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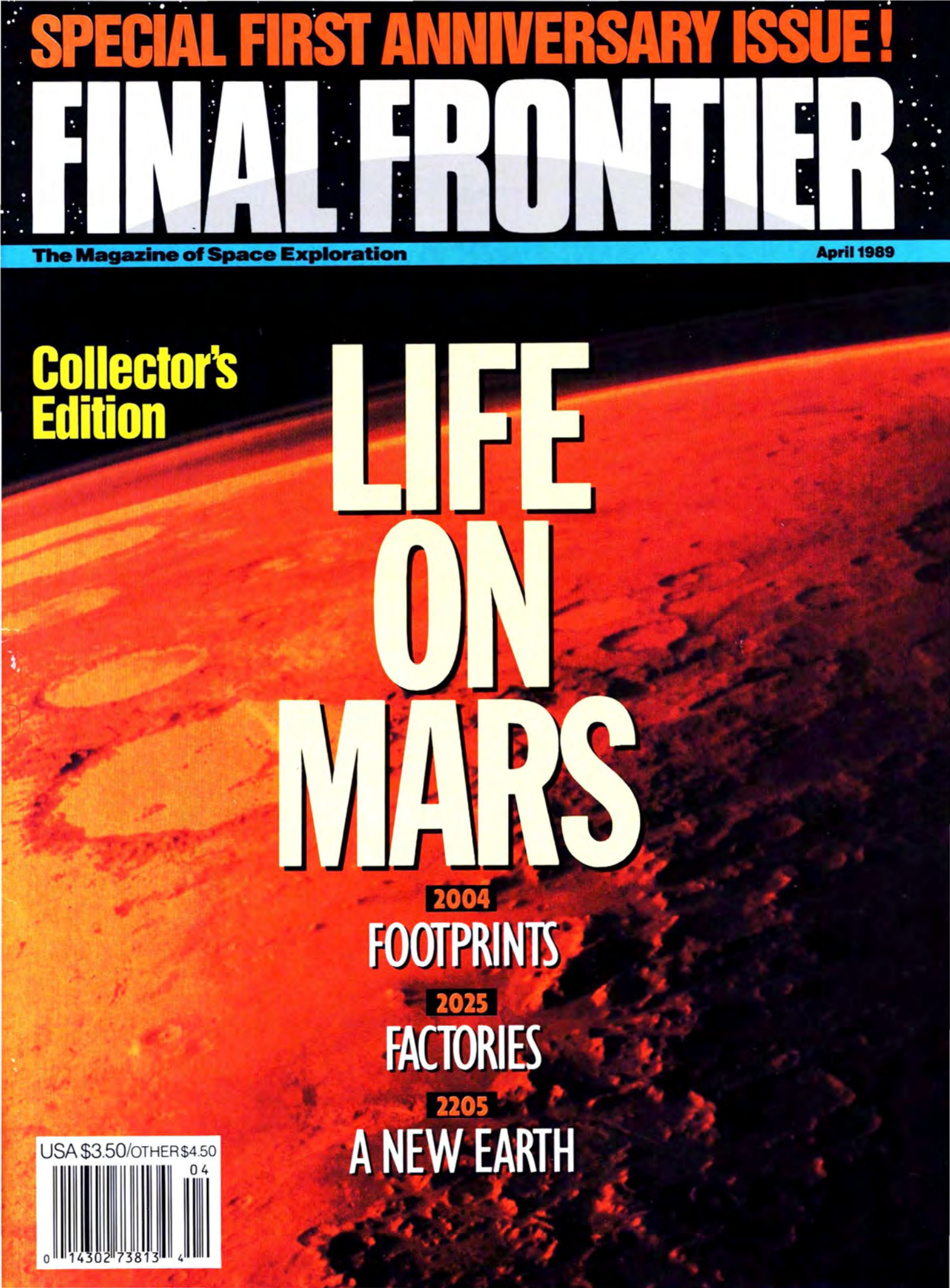
FINAL FRONTIER

The Magazine of Space Exploration

April 1989



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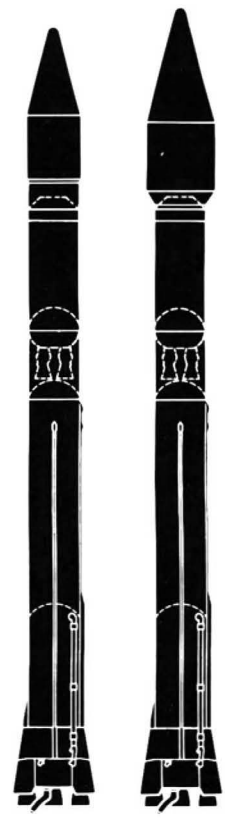

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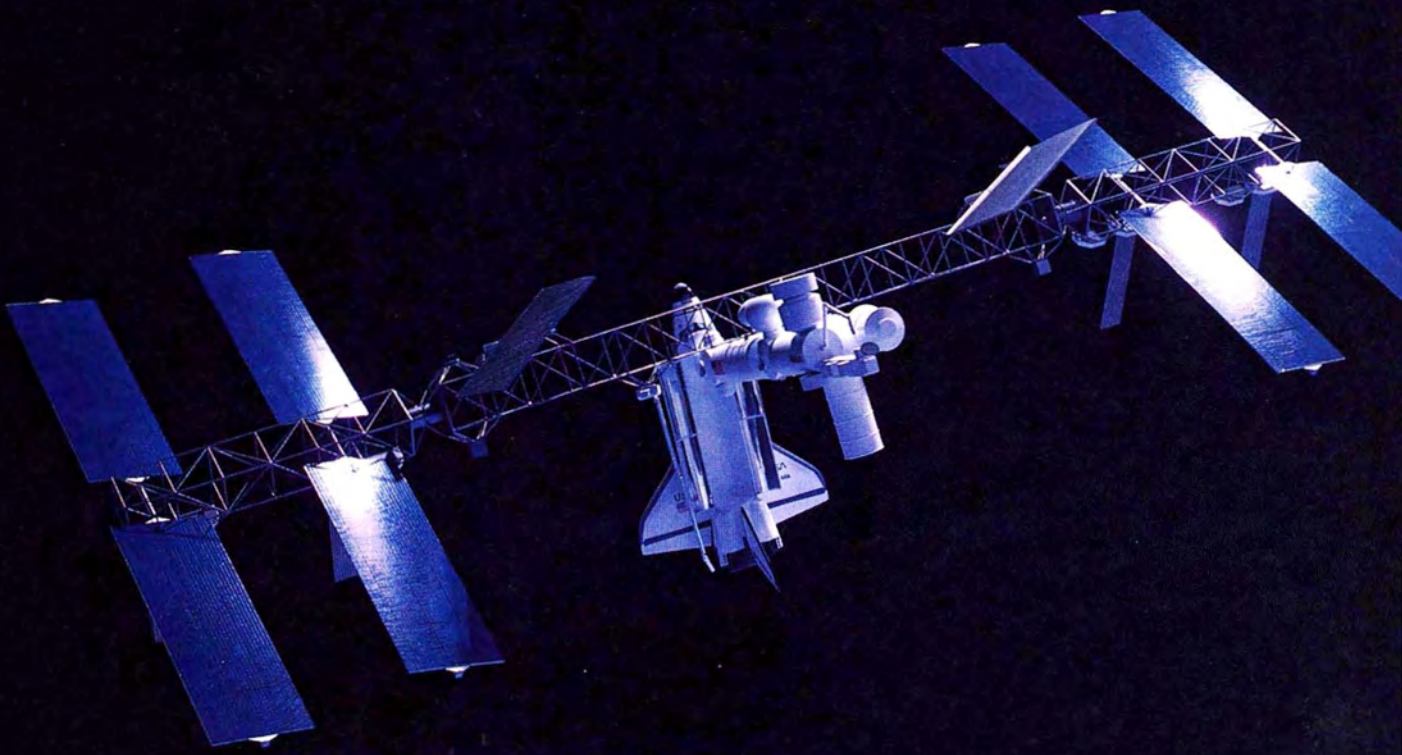

"Knowledge Engine"

Stimulant to industrial genius, way-point to the galaxies,
classroom for science, but most of all,
a gift of vision from this generation to its children.

Freedom Space Station

MCDONNELL DOUGLAS

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Who says Mars ain't the kind of place to raise your kids? See the stories beginning on page 30.

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HARRIS

FROM THE PUBLISHER

MARGARET HUBER

At this year's first annual FINAL FRONTIER bash we celebrated the past year's success with the traditional poker game lasting into the wee hours of the morning. Jokers wild, five card draw. On the first hand I was dealt *five* aces. A buddy of mine, who was as floored as I was, wondered aloud what the odds were. By now I should be accustomed to calculating astronomical odds, but I was unable to give him an answer. I'm sure it means something good, though.

A while back I was having a conversation with a space entrepreneur who also had dabbled in publishing over the course of his adventurous career. He ranked launching a magazine a close second to launching rockets, risk-wise. Some people say it's the other way around. But that's if you listen to the publishing experts, who'll tell you that you can't make it without screaming "Elvis is Alive!" on your cover every month (and don't think we haven't considered it).

I've decided that there are one of two conditions that must be met in order to start up a magazine. Number one is having knowledge, skill and talent, lots of it–a pretty good description of the staff here at FINAL FRONTIER. Number two – which I admit describes me better – is *not* knowing that you are supposed to fail. If people really understood all that's involved with introducing new, untested ideas to the world, many would decide to open up a donut shop instead.

On a larger scale, I think the same principle applies to the much more important risk that our whole society will face when we send the first humans to Mars. The journey will certainly require knowledge, skill and talent from those brave few who build and board the Mars-ships.

As for the rest of us, it will require that we make an investment without being sure of the payoff. Frontiers are like that. We don't know exactly what's waiting for us on the other side, but we go anyway. Failure is always a real possibility, as the history of exploration reminds us. But *not* to go is a kind of risk as well.

We entered our first year of FINAL FRONTIER with all sorts of dreams. It was a year of beating the odds. A year of establishment. In year two, we intend to do something about seeing our dreams come true.

What's so special about our one year anniversary? Only that we're still here, with an even stronger commitment to our cause. And that means that you might find us on sale – in about 20 years – at the first newsstand on Mars.

Ever upward,

William Rooney

William Rooney
Publisher

FINAL FRONTIER

THE MAGAZINE OF SPACE EXPLORATION

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LETTERS

Bigger is Better

I must comment on the article "At Home on the Space Station" (August 1988).

The article refers to the now-incinerated Skylab as having "coffin-like" standards. With the internal volume of a large three-bedroom home, Skylab was huge and had a lot more open space than the new station depicted.

If the Saturn 5 rocket had not been abandoned entirely for the shuttle, the new space station modules would not have to be restrained to trailer-sized dimensions; [the station] could incorporate four Skylab-class modules, with a usable volume more than twice the present design. A Saturn-class vehicle could haul all other components in perhaps three flights.

Before America spends its money foolishly on an entirely shuttle-dependent design for a space station, perhaps it should focus on rebuilding its lost capabilities and open up Earth orbit with much more Buck Rogers for the buck.

L. H. Hashman
Chatsworth, California

Last Word

I was surprised and disappointed by *Final Frontier's* failure to provide me the opportunity to make a timely response to Mr. George Koopman's anserine outburst in your [December] issue.

Wm. R. Claybaugh II
Camarillo, California

Since the "Letters" section of Final Frontier *is an open forum, we don't edit letters for content, nor do we solicit opposing views to those selected for publication. We regret any embarrassment to Mr. Claybaugh.—Ed.*

More East, Less West

I would like to see more coverage of Soviet space activities in your magazine. All too often, the American press minimizes Soviet achievements, exaggerates their setbacks or just ignores them altogether.

Perhaps Americans simply don't like to see adversaries succeed in areas which Americans are having problems. True, the Soviets don't provide nearly enough information to compare with what NASA offers; however, if the western press showed more interest in providing complete, balanced and fair coverage, then perhaps they would be more open.

I will defer requesting a subscription until I see better coverage of non-American space activities.

Hans Boldt
Don Mills, Ontario

Oops—Sort Of

Your information regarding the Apollo 16 P&F satellite (Database, December 1988) is incorrect. It remained in orbit until the end of 1972 [according to] *The History of Manned Spaceflight* by David Baker.

Jeffrey S. Buch
Costa Mesa, California

Actually, we're both wrong. The Apollo 16 subsatellite remained in lunar orbit until May 29, 1972. The source we used listed the right month and day, but the year was incorrect.

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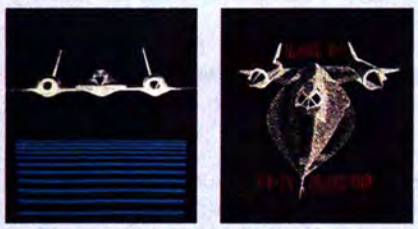

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F-15 EAGLE

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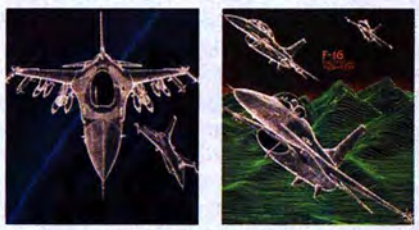

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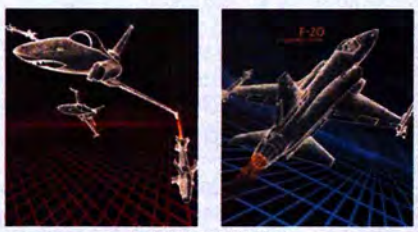

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(actual shirt photos)

KC-135 STRATOTANKER

C-130 HERCULES

C-141 STARLIFTER

THE OBSERVATORY

Dear Mr. Bush

Leadership starts at the top.

▼ ▼ ▼

By Charles D. Walker

Mr. President, you have told us that you are "fully committed to America's space program." That commitment needs to manifest itself soon, and in many ways. The most basic is leadership. You, Mr. President, must be visible and vocal about goals and budget; anything less will result in severe erosion of your proposals.

Second in importance after White House leadership is the necessity for strong, qualified personnel. By this time your NASA administrator should have been named. The administrator's active presence and participation within your councils—and control over NASA's budget early this year—is vital. Historically, the late (summer!) confirmations of past NASA heads have caused the agency's budget and programs to be ravaged and crippled.

NASA is a special agency within the collection of federal institutions. Its mission is unique, and the skills of its personnel are not common and are becoming less available. NASA is required to perform at a level—and with a visibility—that necessitates special consideration of its institution, organization and personnel. There are those who will strongly disagree with this; they want to muzzle the agency from stating its justifiable needs. Such voices will ruin the future.

I heartily agree with your reconstitution of the National Aeronautics and Space Council within the White House. The council's role today needs to be as the integrator of overlapping civil and defense space program interests. And with the Vice-President's leadership, it needs to recommend future directions.

But the council will not work significantly better than what we already have, unless the NASA administrator has a standing more in line with that of the cabinet-level members who will share seats on the council.

In addition, the Vice-President cannot be the day-to-day manager of civil space activities. It seems therefore appropriate for the NASA Administrator to be your advisor on all civil space matters (NASA does not have all civil space activities under its roof). With this elevated responsibility, the Administrator would manage all government civil space interests, just as your Director of Central Intelligence does for the intelligence community.

Mr. President, during the campaign you stated that you "support the full participation of the private sector in revitalizing our space program." One very significant means to that end is to give industry and the science community seats on the council, as was the case at the time President Nixon dissolved it. Industry will always be quicker to invest if it is allowed to participate in the process.

Civil space activities take years to develop. Our space projects cannot be put on hold to be called up "when things are better." They must have consistent national commitment to efficiently utilize the people and dollars invested in achieving their objectives. This means *long-term* support: greater than a single fiscal year or the two years of a Congress' life! In achieving this there is no way around forging bipartisan political support for our space goals and the programs to reach them.

I agree with you wholeheartedly, Mr. President, that the space station is key to all our future space endeavors. Space station Freedom is a project that already has bipartisan support. There have been enough studies, hardware is being built and last year Congress authorized its budget for the next three years. Now, the appropriations must follow!

The Candidate supported space. What will the President do?

Station Freedom is vital in many ways, especially in the area of international cooperation. Europe, Japan, Canada and the United States will not simply be traveling in space together. We will be working there for our combined scientific self-interest, in healthy economic competition. We will be leading the free world's advance in the utilization of the space frontier by building and operating Freedom.

International cooperation in large space efforts is certainly advantageous, but there is a trap. No country that gives up an independent capability (such as large launch booster access to space) is a leader. That country soon will end up paying for its access to space. Do not start us down that path.

I believe that you understand the necessity for this nation to be economically competitive. I want to emphasize that the technological base for our future competitiveness has been severely neglected. We just can't do new things in a cost-effective manner, on schedule, without a strong foundation of modern technology. And that includes producing those unique substances in orbital laboratories for world markets or going to the Moon and Mars. These are all goals worth pursuing.

Humanity's next challenge is space—its exploration and development for human benefit. We must be a leader in that or we are lost. You can find a way—we can find a way. The American people will support you.

Charles D. Walker was America's first "commercial astronaut," flying as a McDonnell Douglas payload specialist aboard three space shuttle missions. He also is chairman of the grassroots space lobby, Spacecause.

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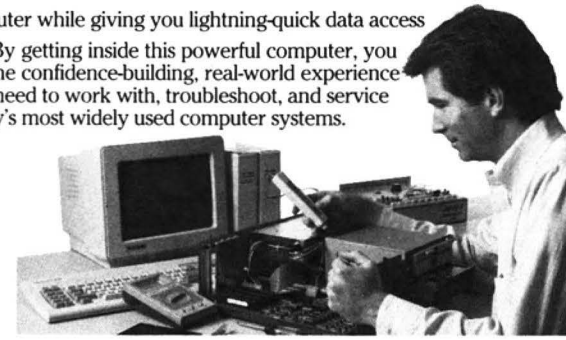

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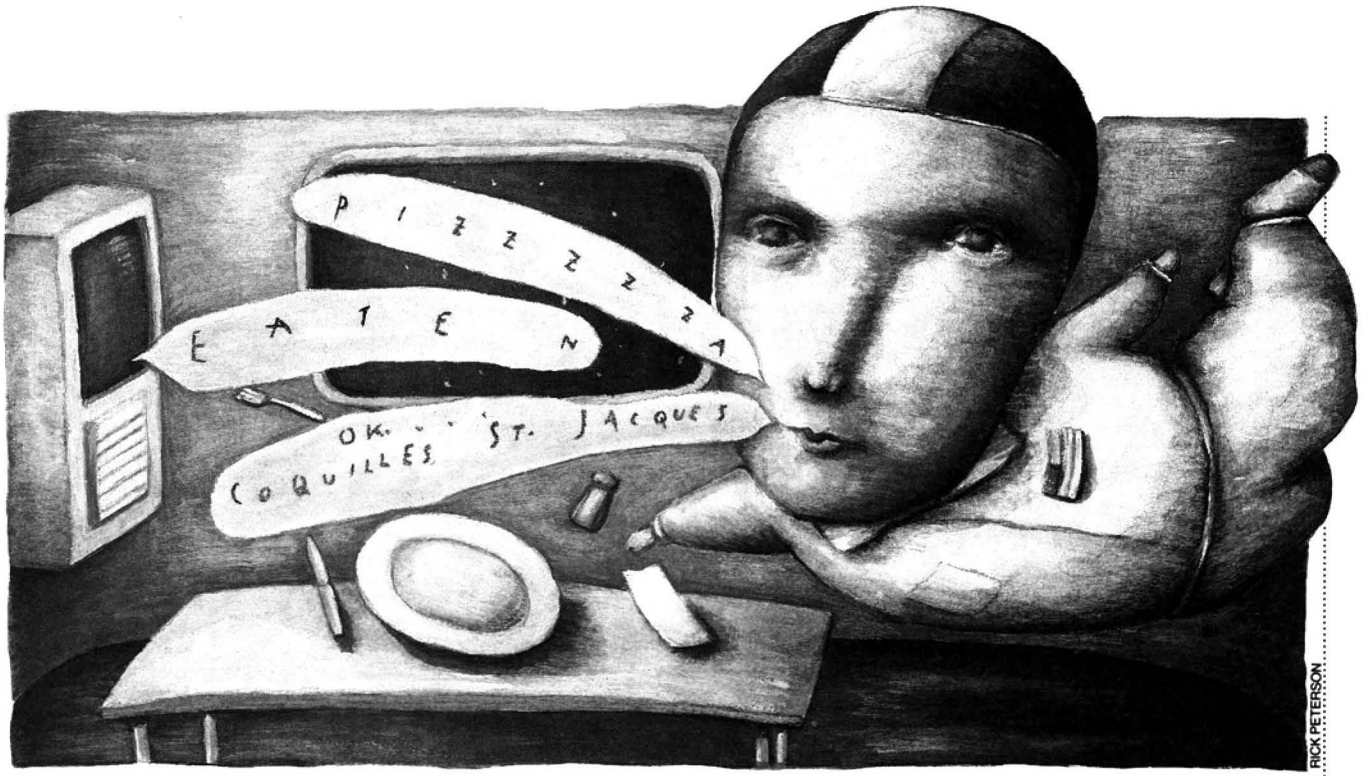


RICK PETERSON

FREEDOM OF VOICE

Aboard space station Freedom, an astronaut floats up to a wall-mounted speaker and pushes a button. A computer asks, "Welcome to VAIS. May I take your order?"

"I'll have beef enchiladas and nachos. No, make that corned beef on rye," replies the astronaut.

What sounds like an out-take from *2001* is actually the handiwork of David Rodriguez, a cooperative education student at NASA's Johnson Space Center in Houston. Last summer, Rodriguez designed the "Voice Activated Inventory System" (VAIS) to keep track of the 14,000 items planned for the menu aboard NASA's international space base of the 1990s.

Because Shuttle missions are short, keeping track of the food supply isn't a problem; but the space station will have a 90-day food supply *plus* 20 percent extra for menu changes or snacks.

Responding to 27 word commands, the VAIS will tell an astronaut where each food item is, and will track each morsel as it's eaten. The astronaut will be able to browse through the entire file, look only for certain types of food, or view his or her own personal menu.

An important feature of the inventory system is its flexibility, which allows for mix-and-match meals, even though the choices will be limited to the 28-day menu each astronaut selects prior to flight. "EATEN" items can't be chosen again until the crew module has been restocked and the computer's FOOD file is restored.

VAIS will be able to distinguish between actual commands and background conversation. Rodriguez has programmed the computer to recognized commands from two male and two female voices; the digitized VAIS voice belongs to Rodriguez. Command words, such as "turn on" and "turn off," eventually will replace the push-to-talk button used to activate the system.

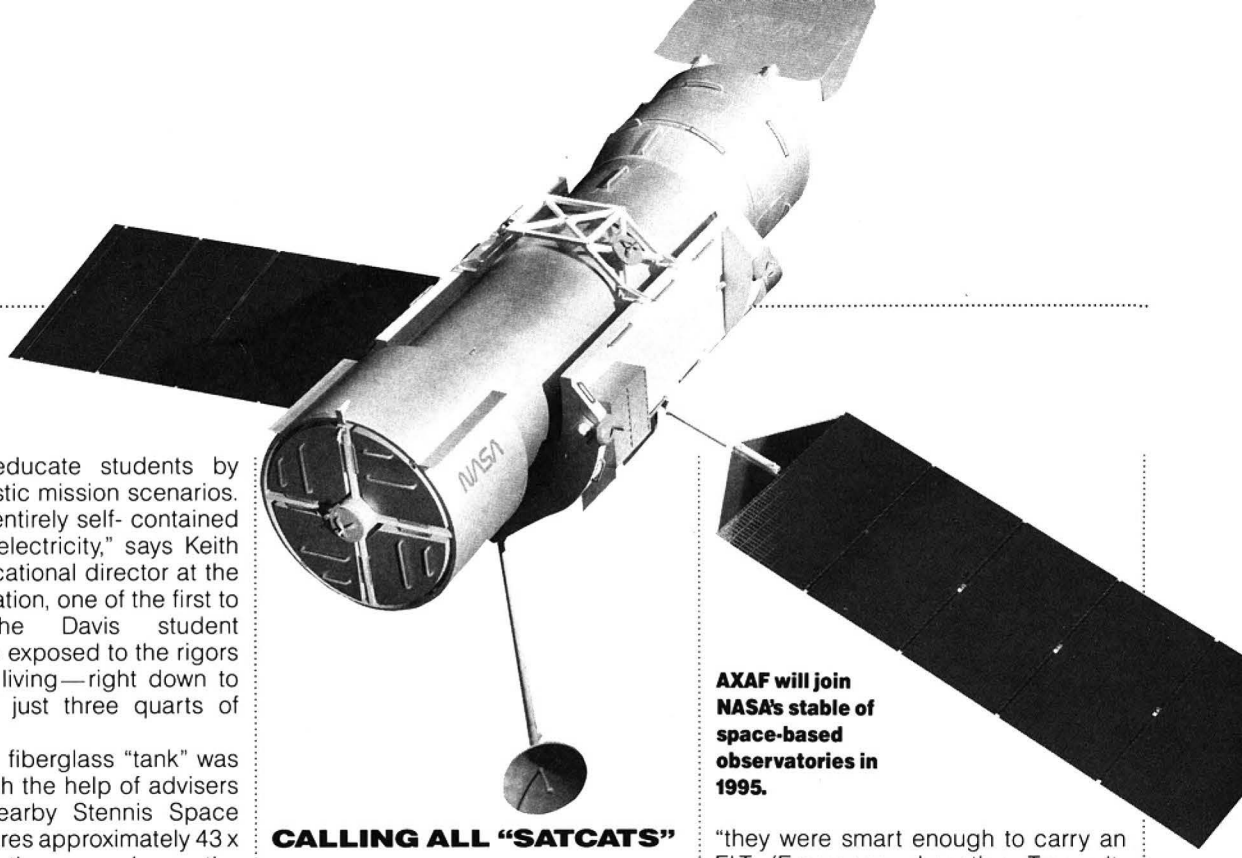
Tests in the Freedom mock-up in Houston show VAIS has great potential for tracking the entire space station inventory. Bar coding and touch screens are also under consideration, but VAIS has the advantage of being hands-free. —*Linda Kofler*


JANE FLYNN

ONCE AND FUTURE ASTRONAUTS

There's the Davis Planetarium Space Station in Jackson, Mississippi...the Starship McCullough in Woodlands, Texas...and the School Space Station in Austin, Texas. Space "habitats" like these are popping up across the country, with one thing in common: they're all for students.

Though they lack the zero-g conditions of Earth orbit, the ersatz stations



AXAF will join NASA's stable of space-based observatories in 1995.

are used to educate students by simulating realistic mission scenarios. "Our station is entirely self- contained except for the electricity," says Keith Crumpton, educational director at the Davis Space Station, one of the first to be built. The Davis student "astronauts" are exposed to the rigors of spaceborne living—right down to showering with just three quarts of water a day.

The two-story fiberglass "tank" was put together with the help of advisers from NASA's nearby Stennis Space Center. It measures approximately 43 x 12 feet (virtually the same size as the planned modules for space station Freedom) and includes audio and visual hookups to a "Mission Control Center" in the planetarium.

Other student stations aren't quite as elaborate. The Woodlands space base, designed and built by enterprising youngsters, is located on a stage. The 20 x 8 foot Austin station contains modules that accommodate various classroom experiments, including a permanent aquaculture project.

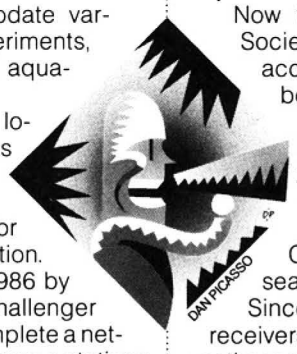
A prototype station located in Houston, Texas has a special distinction: it was built by the Challenger Center for Space Science Education. The center, created in 1986 by the families of the Challenger astronauts, hopes to complete a network of 50 educational space stations around the country in the next few years. These "Mission Sites" will be complete with environmental and communication controls and human physiography experiments.

The rush to construct scholastic space stations appears to be a cross between educating children for a techno-future, and satisfying the students' own desire to *contribute* to that future. The results have been overwhelming—at the Davis Space Station alone, close to 1,000 student applications have already been received for the summer program's 64 slots.

—Patricia Barnes-Svarney

CALLING ALL "SATCATS"

Early in his flying career, Charles Lindbergh parachuted from his crippled airplane, thus becoming a member of the Caterpillar Club for "hitting the silk." Modern-day military aviators who leave a stricken aircraft using a Martin-Baker ejection seat receive an exclusive M-B tie, courtesy of the manufacturer.



Now the recently-formed World Society of SATCATS also is accepting members. But membership is rather selective, and space, not aviation, is the tie-in. To "join," you must have been rescued from a mishap through the efforts of the COSPAS/SARSAT satellite search and rescue system.

Since 1982, COSPAS/SARSAT receivers mounted on American weather satellites and Soviet "Kosmos" spacecraft have helped to locate more than a thousand pilots and sailors who might otherwise have been lost. When one of the polar-orbiting satellites picks up a distress call, it relays the signal to the nearest ground station, which then dispatches a rescue team.

Dr. E. Jeff Eustis, a Memphis, Tennessee surgeon who was rescued by a Danish helicopter after landing his light plane on the Greenland Ice Cap, is the temporary SATCAT chairperson. He supposes that some people may be reluctant to join, as "they may be ashamed about admitting that they lost their craft." But he also points out that "they were smart enough to carry an ELT (Emergency Location Transmitter—one type of device that sends out a cry for help to the orbiting satellites), so they should be proud."

The SATCATS don't discriminate between air or sea rescues, so both sailors and airmen qualify for membership. Finding some candidates may be a problem, however; the identities of those saved by certain military or governmental rescue units are classified, even under the Freedom of Information Act.

Eustis simply says that if you're eligible, "Please don't be shy."

—Brian Nicklas

THE CAN WITH THE X-RAY EYES

Since Earth's atmosphere filters out much of the natural electromagnetic radiation emitted by stars, ground-based astronomers have a relatively narrow window on the universe. The only sure way around the problem is to get above it all by placing astronomical observatories in orbit.

One of NASA's most exciting space-based observatories in the 1990's will study the heavens in the x-ray portion of the spectrum. Officially, its name is the "Advanced X-Ray Astrophysics Facility," but most everyone calls it by its acronymic nickname, "AXAF."

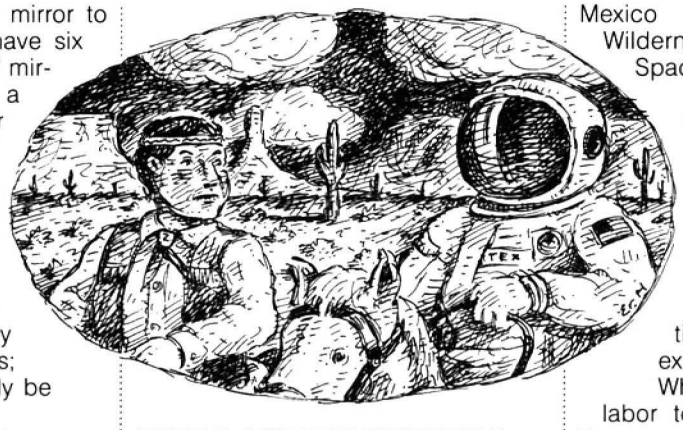
Due to be launched by the space shuttle or a Titan 4 expendable booster in 1995, AXAF will be a large cylindrical satellite weighing around 11 tons. Unlike the Hubble Space Telescope,

which will use a traditional mirror to create images, AXAF will have six pairs of "grazing incidence" mirrors— cylinders with a reflective surface on their *inside* walls. Viewed from the front, the mirrors will look like tin cans nestled one inside the other. This unusual configuration is necessary because the high-energy x-rays must strike the reflectors at very shallow—"grazing"—angles; otherwise, they would simply be absorbed.

AXAF's X-ray images of the hot gases hurled into space by exploding stars may provide clues to the stars' chemical makeup. AXAF could even play a part in discovering the age of the universe by allowing scientists to arrive at a more precise value for the so-called "Hubble constant," which relates distance to the rate at which the universe is expanding.

AXAF will be able to see twice as much of the x-ray spectrum as its predecessor, the "Einstein" observatory launched by NASA in 1978. It also will be 100 times more sensitive, and will have 100 times better resolution.

Just as important, the new observatory will have an indefinite life span. Because it's designed to be refurbished and upgraded in orbit by shuttle astronauts, AXAF's x-ray eyes should give us a more complete picture of the universe well into the 21st century. —*Robert G. Nichols*



ERIC HANSON

THE LAST FRONTIER?

Gold rushes, cattle drives, railways and wagon trains—the settlement of America's frontier is a sweeping story of the pell-mell building of a nation. It's a sad litany too, with scarred lands, decimated animal populations, displaced peoples and dirtied air, water and soil. Is this is the fate we'll bring to the worlds beyond Earth?

M. Jane Young is afraid so. A professor of American Studies at the University of New Mexico, she examines the "great white explorer's" achievements from the perspective of the Native American. Now she's riling the space program's Manifest Destiny adherents by calling for a more ecologically sensitive and less "explore-and-conquer" oriented viewpoint in NASA's long-term planning. Young presented her ideas at a recent University of New Mexico conference, "The New Wilderness—Values in America's Space Program."

"One scientist told me, 'It's human nature to explore and exploit. The entire world feels that way.' That's an Anglo-European perspective. The metaphor of space as a frontier disguises the reality that space exploration is essentially a materialistic, exploitative enterprise."

While industrialized nations labor to put humans into space, Young says, people such as the Navajo and Pawnee regard objects in the sky as living beings, and think of humans, Earth and cosmos as already interconnected. Understanding the kinship is an internal journey, exploring one's self in relationship to the universe.

Young stresses that she is not advocating anti-intellectualism, but would like to see a "cultural pluralism" integrated into NASA's thinking, offering alternative philosophies a say in our reach to the stars.

"Even the Native Americans wouldn't say let's not have any space program at all," she says. "I'm just concerned about respect for all worlds."

—*Maura J. Mackowski*

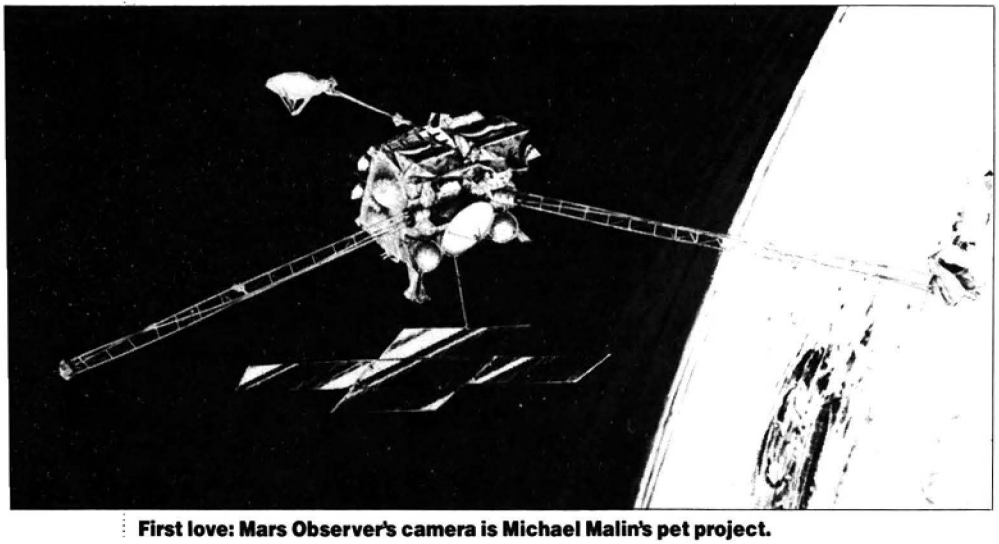
FIR$T THINGS FIR$T

Who wouldn't know what to do with almost a quarter of a million bucks?

Arizona researcher Michael Malin says it's a nice windfall, but his $240,000 MacArthur Foundation grant won't help with the preeminent project on his calendar right now: construction of a camera for the next U.S. Mars mission. So the 38-year-old geology professor at Arizona State University simply puts the award out of his mind.

"It's my view I received the money to be creative," he says. "I can't be 'creative' until I complete this project. I haven't even had the time to think about how I'll use it."

The MacArthur Foundation attaches no strings to its grants, and ties them to no specific project. Malin receives the money (about $50,000 per year), pays the taxes and bankrolls the balance rather than paying the bills now. According to the scientist, his first



First love: Mars Observer's camera is Michael Malin's pet project.

chance to use it for "brainstorming" will have to wait until he completes work on the sophisticated camera slated to be carried by NASA's Mars Observer spacecraft, which will conduct a geochemical survey of the planet beginning in 1992. Until then, Malin says, his research "has precedence over everything else in my life."

The $13 million Mars Observer camera is being developed in a Pasadena, California warehouse by Malin and Cal Tech's G. Edward Danielson. It will be powerful enough to obtain a clear image of car-sized objects on the Martian surface. NASA doesn't expect to find any Volkswagens, but it does hope to snap some shots of the old Viking landers, stranded there since 1976.

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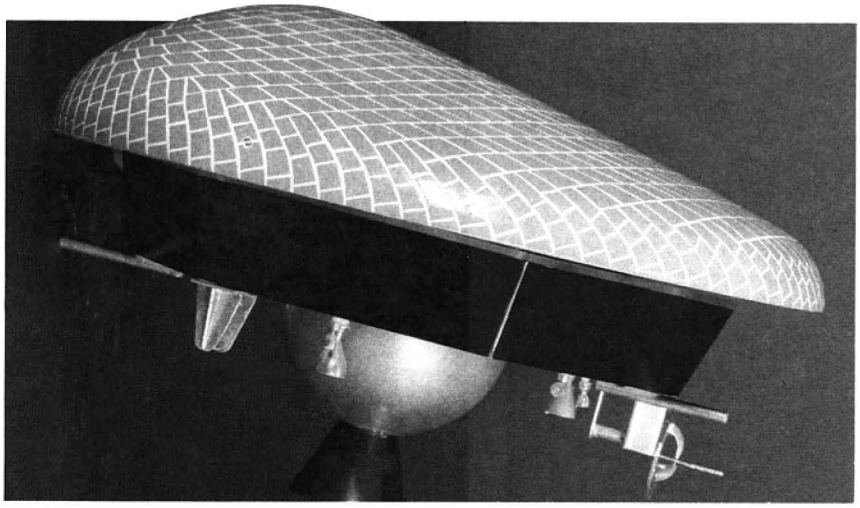
—Gary Taylor



The shuttle's Aeroassist Flight Experiment may pave the way for bigger and better aerobrakes.

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— Linda Billings

GALACTIC EVENTS

MARCH 10-12

Chicago. First Intergalactic Expo, a multi-media weekend of science fiction, fantasy and science fact. Space- related events include talks by NASA speakers on the space shuttle, benefits of space technology and space structures, and a screening of the IMAX film "The Dream is Alive." Information: (303) 293-2228.

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DAN PICASSO

GLOBAL CURRENTS

Inside Star City

The Soviet college of cosmonaut knowledge

▼ ▼ ▼

By Devera Pine

Star City isn't the sort of place that your average tourist in the Soviet Union gets to see. "Zvezdniy Gorodok" is not only home to some 3,000 people involved in the Soviet space program— it's also the cosmonauts' main space training facility. Still, in the era of *glasnost* the Soviets are becoming more agreeable to letting foreigners, including journalist-authors like my husband and me, into places that used to be off-limits.

The town is about an hour outside of Moscow, and the only way to get there is by car. In this case, "car" meant a beat-up taxi weaving in and out of heavy trucks at 60 to 75 mph on city streets, then a pastoral drive past woods, farms and small wooden houses called *dachas*. The entrance to Star City was easy to spot: In the midst of all this open country stood a monument of a Russian MiG and the name of the place in big silver letters.

Star City looks much like a typical American college, except that there are apartment buildings (and one hotel named "Orbit") instead of lecture halls. The place is pristine. Unlike the streets of Moscow, there were no long lines of people waiting to purchase food—in fact, no lines of any sort.

The entrance hall of the training center has a large bulletin board with photos of the current crew aboard the Mir space station. It also shows a running tally of the number of days they've been in orbit (238 on the day we visited).

Boris Volynov, one of the original cosmonauts who trained with Yuri Gagarin, arrived to show us around; like all the cosmonauts we saw that day, he wore his military uniform. Our first stop was the full-scale Mir trainer (with attached Kvant astrophysics module) in which cosmonauts run through their mission activities. A mockup of Mir's forthcoming addition—an Earth resources module, scheduled to be launched sometime this year—sat in the back of the training room.

We weren't allowed inside the trainer. In fact, we viewed it from a sort of observation deck one flight above. But the Soviets gladly let us take photos—so many that they joked we had to be American spies.

The tour also included a close-up look at Soviet space equipment. In one room, two showcases displayed typical space food and tools, including a flare gun that Volynov said a cosmonaut could also use to shoot pigs in the forest to survive in an emergency! On display in another room was a pressure suit and a spacesuit for extravehicular activity (EVA). The mannequin wearing the pressure suit was seated in a Soyuz contour couch. He looked pretty cramped; the couch forces the knees against the chest, where they're held by restraints.

JACK MOLLOY

The Soviet EVA suit differs from the American version in that cosmonauts enter it through a "door" in the back. Volynov compared it to climbing into a refrigerator, and in fact, it did somewhat resemble a freezer door.

On the walk over to the neutral buoyancy tank where cosmonauts rehearse space tasks underwater, we noticed a building under construction. We found out once we returned home that it's to be the Soviets' space shuttle training facility.

No one was using the water tank that day, so it was dark. Instead, we watched a videotape of cosmonauts in action at the facility, practicing to attach solar panels to Mir manually. Volynov laughed at a suggestion that they market the video in the United States. (But he was interested in *The Right Stuff*—the Mercury astronauts were his contemporaries. When we returned home we sent him a copy, evidently the first one to reach the USSR.)

The final leg of the tour was a walk across the complex for a look at a statue of Gagarin and the Star City museum. The main sidewalk is called the "Road of Heroes." Cosmonauts returning from orbit walk this road in an informal ceremony, during which the entire population of the town turns out to place flowers at Gagarin's statue. Actually, fresh flowers are put on the statue's base every day. Gagarin is revered almost religiously.

At the other end of the complex, Star City's museum has Smithsonian-quality exhibits, but it's not open to the general public. Among the displays are Gagarin's desk, Alexei Leonov's spacesuit from his first-ever spacewalk in 1965, and a used Soyuz spacecraft (the only one we saw on exhibit in the USSR). There's even a bit of Americana: Scott Carpenter's watch, an impromptu donation from the Mercury astronaut when he visited the museum.

One final note for the prospective tourist: Star City's cafeteria has the best ice cream in or around Moscow. And the pastries aren't half bad, either.

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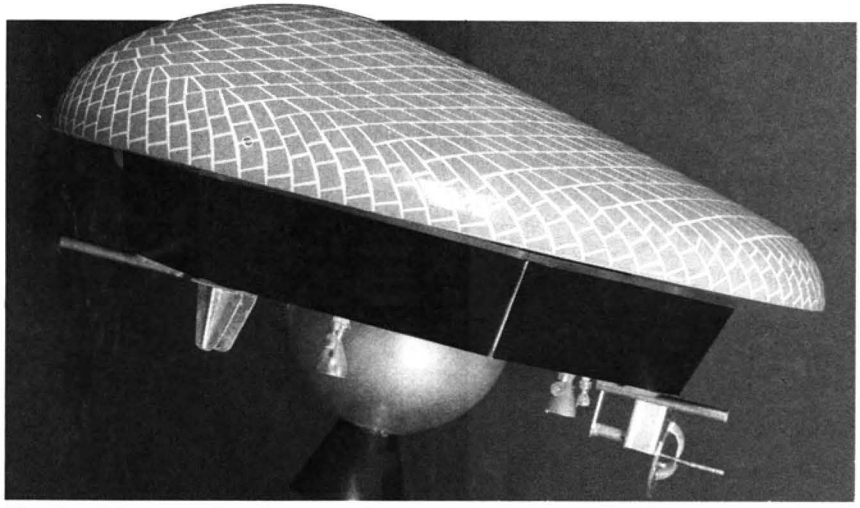

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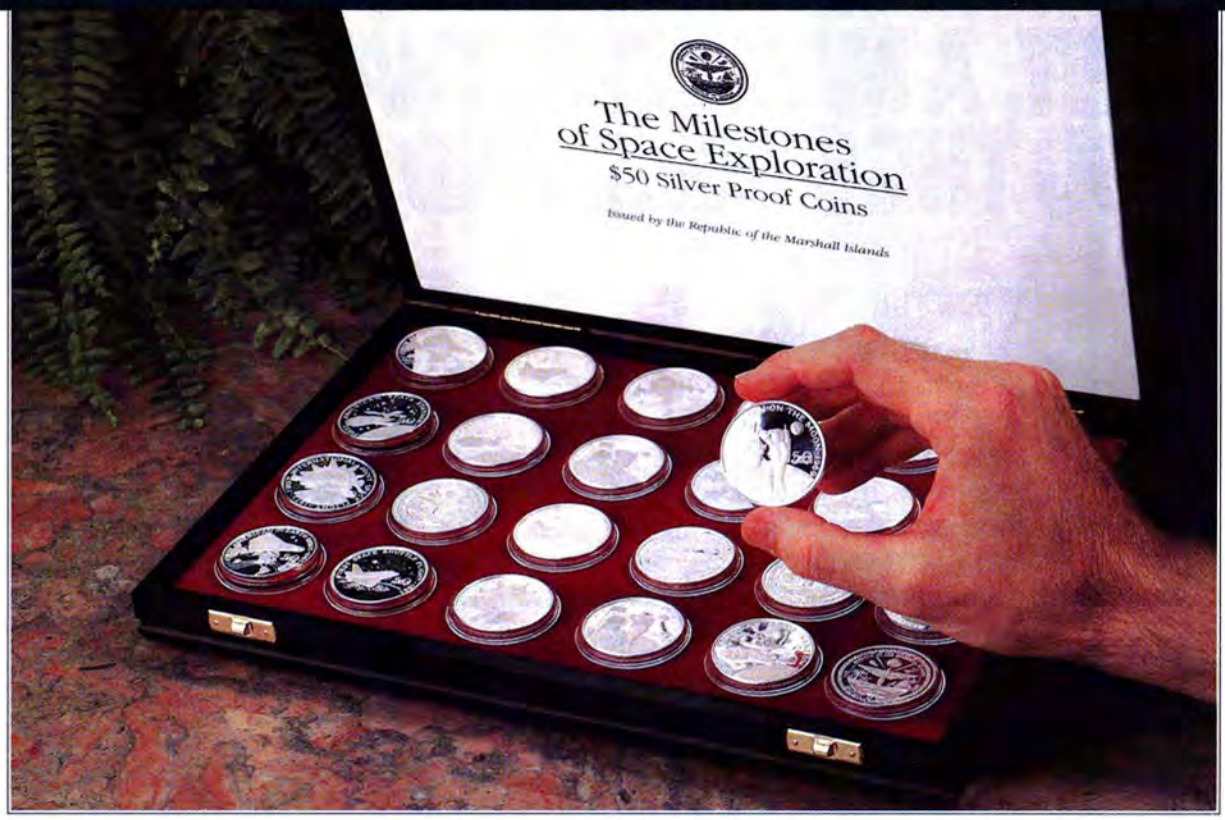
DAN PICASSO

HONORING THE 20TH ANNIVERSARY OF MAN'S FIRST WALK ON THE MOON...



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You and your whiz kid buddies have just invented the revolutionary "Spacewidget," and it's going to make you millionaires. You'll borrow ten grand from Uncle Mel, line up some customers, then wait for the cash to pour in.

That's often the thinking of young space entrepreneurs, says C. Dennis Ahearn, a space law expert in Washington, D.C. "The biggest failing of new companies is that they don't establish a strong business," he says. "They make the mistake of thinking the sheer strength of their idea will carry them through."

Ahearn says a great idea alone won't get you financial backing. He believes success comes by developing thorough, specific business plans, and having an experienced business leader to run the show from the start.

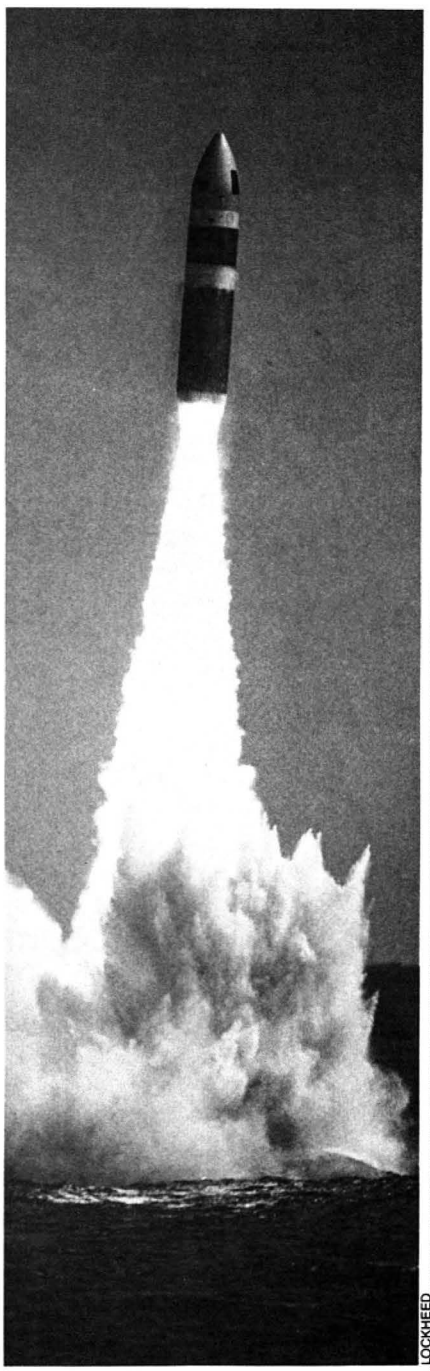
Beware the red tape if you're marketing a rocket booster, advises Ahearn. NASA and the armed forces want assurance that their launch facilities will be properly insured in case of an accident on the pad. Before the Department of Transportation issues a launch license, the State Department must know if your rocket will be used outside the United States. And the Defense Department wants to make sure you're not launching a nuclear missile or virus bomb.

"We have to prove it's definitely not a front for a communist regime," quips Ahearn. *—W. Dan Leonard*

LOFT'S Labour Lost

With the flight of its Santa Maria sounding rocket last November, E-Prime Aerospace Corporation of Titusville, Florida claims to have launched America's commercial space booster industry.

The rocket was just ten feet tall, and it reached an altitude only 15,000 above its rented concrete stoop on Cape Canaveral. But "LOFT-1" (for E-Prime's first Launch Operations Flight Test) itself wasn't the whole story.



LOCKHEED

Poseidon: From undersea to beyond the atmosphere

"This thing has been a pathfinder from the very first day in getting through all the regulations it takes to launch from a government facility," explained E-Prime spokesman Jim Mizell.

Stuffed into a red capsule atop the blue and white rocket were four student experiments and some souvenirs that included envelopes postmarked for later sale as "space mail."

Conspicuously absent was Miss Kittee, the rocket's only scheduled "passenger." A Rhode Island entrepreneur, Daniel Patrick Jr., had signed a $1.5 million contract to fly his plastic "intergalactic citizen doll"—or the powder to make her— aboard 52 E-Prime rockets in five years. Reportedly, Patrick disagreed with the company over exclusivity provisions in the contract.

The flight offered only half a minute of microgravity, and the rocket carried its payloads for free. E-Prime lost more than $250,000 on the mission.

But the company's founder, Bob Davis, was undaunted. "Christopher Columbus had skeptics," Davis declared. "They make you more determined than ever." *—Beth Dickey*

Poseidon Venture

In the Recycling Department: The Lockheed Missiles & Space Company says it's willing to ante up $50 million of the company's own money to convert submarine-based Poseidon missiles into useful, ground-based rockets—if it can line up a couple of government customers.

The U.S. Navy, which bought the Poseidons originally from Lockheed, owns all the hardware the company would need to market the new vehicle to other users. Lawrence Langston, a business development manager for Lockheed, says the Navy promises to put the equipment at the company's disposal, so long as another government agency needs it.

In turn, Lockheed would bear the expense of building a new propulsion and payload third stage, integrating it with the old Poseidon missile, and then adapting the new vehicle to launch about 1,000 pounds into low Earth orbit. The company suggests a per-launch price tag in the neighborhood of $8 million for the new Poseidon, including Lockheed's integration and ground support services.

Langston says if the cost proves

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attractive to government customers, the launcher might even find a market among commercial users: "We see it as a cheap ride—think of it as a Greyhound bus." —*Melinda Gipson*

Mir Today, Gone Tomorrow

Texas entrepreneurs aren't the only visionaries who've shown an interest in the idea of space factories. Soviet microgravity work has progressed to the point where it may require a separate facility to do such experiments away from the orbiting Mir space station. According to Soviet space officials, an automated, "mantended," free-flying vehicle is necessary to develop material samples of any significant size away from the manned station, where crew movement causes disturbances.

Research papers published in the USSR have dealt with advances in growing both protein crystals and semiconductor crystals in orbit, where the absence of gravity and other Earth-bound properties allows scientists to derive larger, purer samples. Those samples may be used in the future as a basis for space-based manufacturing of drugs and computer chips.

Westerners who have discussed with the Soviets the availability of the free-flying factory to commercial companies say the facility is expected to be in use by 1992. Its use by American companies would mark an ironic turn of events for the U.S. government, which has yet to decide whether it will help subsidize such a private facility built in the USA. —*Melinda Gipson*

Armored Tanks

As the amount of space junk circling overhead increases, scientists with delicate instruments in orbit become more and more worried. Now a researcher at Martin Marietta Corp. has designed a protective shield for the proposed Gamma Ray Imaging Telescope, which would use an empty space shuttle fuel tank as the housing for an orbiting astronomical instrument.

Norman Elfer found that computer models at NASA's Marshall Space Flight Center predicting the chance of impact on an object as large as the tank were in error. According to his analysis, the actual risk of a major strike was four times higher than original estimates—which meant the possibility of one hit every nine months for the tank-telescope.

So Elfer and his colleagues invented a "bumper" of aluminum shielding, interspersed with a thermal insulation

America returns to space

with Discovery's payload, TDRS
Tracking and Data Relay Satellite

TRW

blanket and 30 layers of aluminized plastic. To his surprise, studies showed that the bumper worked in combination with the tank's orange spray-on thermal insulation to prevent penetration from debris impacts. The design won a group achievement award from Marshall Space Flight Center, the first for an industrial application project. Its inventors think that Martin Marietta's proprietary bumper-and-insulation system could be used as a space debris shield for any orbital use of the shuttle's external tank.

— Frank Sietzen, Jr.

Homegrown Hummingbird

While most space activists just talk about going into space, members of the Pikes Peak chapter of the National Space Society have started their own rocket company: Hummingbird Launch Systems Inc. Using a small, sub-orbital booster called "Hummingbird," the company hopes to demonstrate technologies for vertical takeoff and landing rocket vehicles, and make a profit at the same time by providing zero-gravity conditions for research payloads.

If Hummingbird is successfully developed, the reuseable launcher should be able to reach an altitude of 100 miles and a maximum velocity of 3,700 mph. It would carry "upwards of 120 pounds," says the firm's vice-president, David Hannah, who is no relation to the David Hannah who founded the Houston-based company Space Services, Inc. Hannah claims that the company has identified 19 potential payloads.

In theory, the booster could be steered by controlling the flow of fuel into each of 64 "aerospike" rocket engines. Selective throttling of the engines during reentry would allow the craft to hover and move in any direction, just like a real hummingbird— hence its name. The first engine test is scheduled for sometime this year.

Development and construction costs could run as high as $1 million; the company already has one backer, but others will be needed before the first vehicle can be built.

—Robert G. Nichols

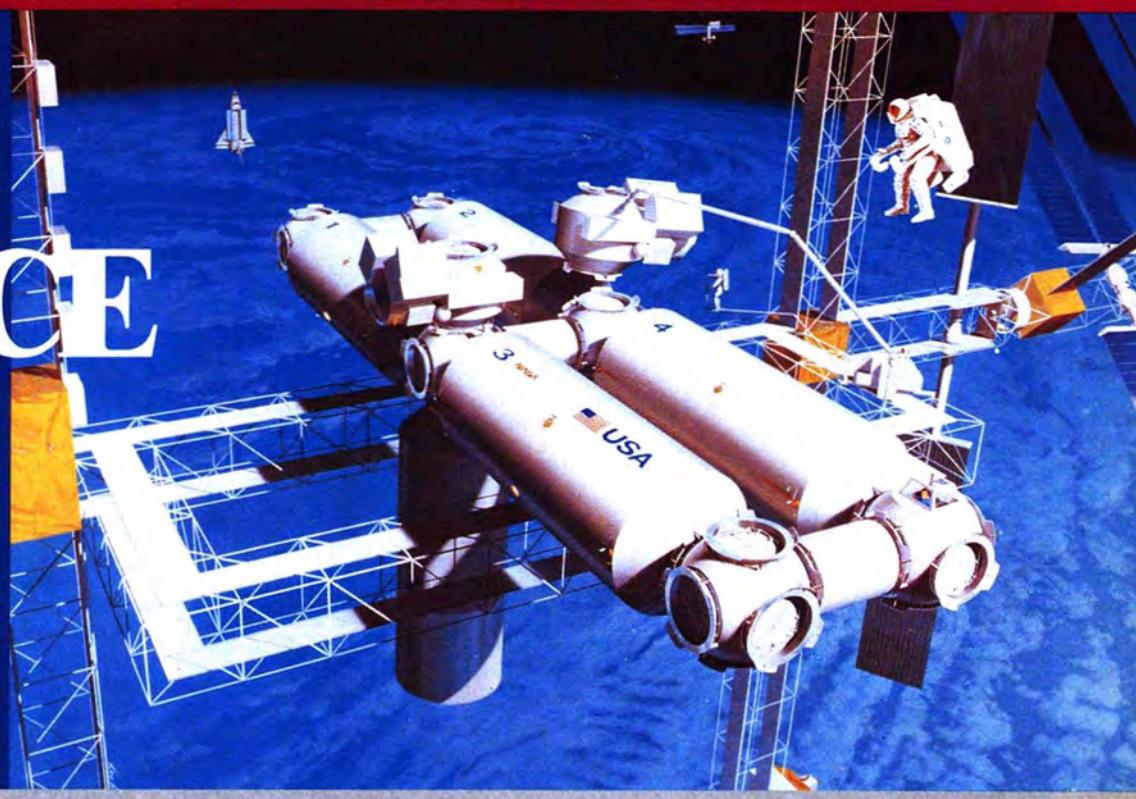
Goodbye Houston, Hello D.C.

Federal policy makers looking for a way to stimulate commercial spending in space have been paying attention recently to the work of the Space Foundation, a non-profit, nationwide network of space business "roundtables."

Started in 1979 by Texas busi-

SPACE

...the final frontier



Our space program is a vital part of a hopeful future. More than any single program, it will determine what our children will inherit tomorrow.

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★ Encouraging greater involvement by private enterprise in developing the space frontier.
★ Seeking the maximum government support for research to advance the technology needed to live in space.
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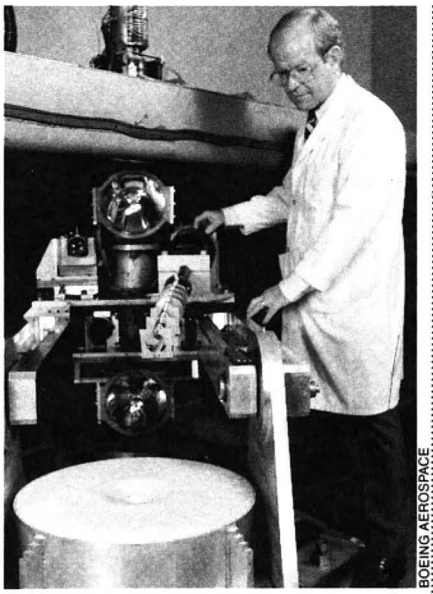
nessmen, the Space Foundation has awarded more than $50,000 in educational grants to students studying business or engineering in space-related fields. The group also is known for its support of regional space business roundtables—luncheon or breakfast meetings where those seeking to stimulate commercial space projects can rub elbows—in Dallas, Houston, New York, Los Angeles, Orlando and Washington.

Policy makers are taking notice because the foundation's board has decided to locate its executive director in Washington, D.C. The move shatters the parochialism of the organization's Houston-area founders, and enhances the group's ability to link space business hopefuls with both potential investors *and* the government.

The new head of the Space Foundation is former Commerce Department consultant Jeffrey Manber, whose early efforts have been well received by NASA and congressional officials. To increase the group's audience, Manber began publishing a monthly newsletter in January to "provide a forum for views and opinions of the business community toward space."

—Melinda Gipson



BOEING AEROSPACE

Robert Schmidt with his home crater-maker.

High Impact

The craters that pockmark the planets and moons can be used by scientific sleuths as "fingerprints" to reconstruct the history of the Solar System. But access to these craters is difficult and expensive to arrange. So Robert M. Schmidt of Boeing Aerospace has devised a novel way to analyze them remotely from his Seattle laboratory.

Schmidt, an aeronautics engineer, uses a powerful industrial centrifuge to simulate impact craters up to a mile in diameter. First he places soil, clay and other suitably planet-like materials on the centrifuge. Then he fires polyethylene projectiles into the samples. The result: laboratory-scale "craters" that simulate the real thing.

Intense gravity fields—Schmidt's system goes up to 600 g's—are the key. By artificially boosting the gravity field, Schmidt increases the potential energy conveyed in the impact, and with it, the size of the crater that he can simulate. Thus, a 40-centimeter crater formed under 600 g's corresponds to a 240-meter crater under normal Earth gravity, or a 1,500-meter crater on the Moon.

Schmidt's goal is to refine the laws that relate crater characteristics to the size and velocity of the impacting body. Boeing's crater studies, funded by NASA, should be helpful in understanding the impacts of meteoroids and space "junk" on spacecraft. □

—Henry Fuhrmann

BACKYARD UNIVERSE

So You Want to Buy a Telescope

Which one has the right stuff for you?

▼ ▼ ▼

By Blaine P. Friedlander, Jr.

Clear evening skies hung over the quiet Washington streets, on which Abraham Lincoln walked alone. Six weeks after the North won at Gettysburg, a question nagged the president:

Why does the Moon appear inverted in a telescope?

A few nights earlier, the president had visited the U.S. Naval Observatory, where, using a 9.6-inch refracting telescope, astronomer Asaph Hall had guided him from lunar craters to the bright exploding light of the star Arcturus.

Lincoln was intrigued enough to return to the observatory and seek out Hall again. Living up to his reputation, the president was honest enough to ask his question, and the astronomer explained the inverted image. Light for the telescope is gathered by a convex lens—both sides bulge out. The light is bent by the lens on its way to the eyepiece, where it is focused. That's why the image appears inverted.

For the modern novice who wants to pick up where Lincoln left off, there are three basic types of telescopes from which to choose: Refractors, reflectors and a combination of the two. All three will allow even the beginner to see lunar craters, Saturn's rings, perhaps Jupiter's great Red Spot, a crescent Venus—even nebulae and other galaxies, provided you have an aperture (opening at the front of the telescope) large enough to bring in enough light. In fact, a 60-millimeter opening is about the smallest aperture useful to backyard astronomers.

Prices vary from a few hundred dollars for a small personal instrument to several thousand bucks for the serious sky investor. If you live in a big city and want to gaze from an apartment balcony, stay within a few hundred dollars. More expensive telescopes aren't going to do you much good, and there's still plenty to see with a smaller instrument.

Regardless of the price and type of telescope you want to own, think seriously about the eyepiece—literally one of the most overlooked parts. Consider this analogy: a telescope's eyepiece is rather like a slide projector. The farther the projector sits from the screen, the larger the image. Bring the projector closer to the screen and the image shrinks, but it is brighter and sharper. That's the beauty of *low* power eyepieces. The lower the power, the sharper the image.

Make sure your telescope is on a solid stand. With a weak support, images dance like swinging sparklers on the Fourth of July. A solid mount with an equatorial setting is best. *Don't* use a camera tripod. They wobble, and they can't follow the sky because they're designed to hold a camera in one position.

An equatorial stand will allow you to follow celestial objects with precision as the Earth moves beneath the night sky. In other words, you won't have to move the telescope up-and-over every five minutes. You can guide the scope consistently with the stars and planets using a single motion.

TOM R. GARRETT

Okay, you've considered the eyepiece and the mount before buying your telescope. Now, which is better: the refractor or the reflector? For a newcomer, that's like asking if a gas stove is better than an electric stove. They both do the same thing.

Refractors cost more, but they're virtually maintenance-free. The tube is covered by a lens on one end and an eyepiece on the other. You set it up and look.

With reflectors, light enters the open end of the telescope tube and heads to a primary mirror at the bottom. The light reflects off that mirror to a secondary mirror, which shoots the light into the eyepiece. Reflectors generally require a little more care; bumpy trips, dust and dirt are this telescope's enemies.

If portability is a consideration, you'll want to look at a Schmidt-Cassegrain reflector. It packages its primary and secondary mirrors in a relatively short tube, and positions the eyepiece at the rear (like a refractor). Cheap they aren't; a Schmidt-Cassegrain usually costs significantly more than other reflectors of the same size.

Combine a refractor and a reflector, and you get a "catadioptric" telescope, which uses both a lens and mirrors. Some telescope enthusiasts argue that because light passes through the lens to two mirrors and an eyepiece, you lose a little of the object in your image.

But the beginner really can't go wrong with any type of telescope. Whether you start with a refractor, reflector or catadioptric, there's plenty to see on a good, dark night. Make your own discoveries or invite friends over—you'll be surprised at how quickly they'll hog the eyepiece. After that, you won't consider yourself a closet astronomer anymore. You'll be an astronomer, period.

Just like that guy Lincoln. □

BOUNDARIES

Small World

A teaspoon of computers may drive tomorrow's spaceships.

▼ ▼ ▼

By T.A. Heppenheimer

When K. Eric Drexler pictures the space suit of the future, he envisions a soft, gray, rubbery-looking thing with a transparent helmet.

"It slips on easily, and the seam seals at a touch," predicts Drexler. "Behind your shoulders, scarcely noticeable, is a small backpack. Below your neck the suit's inner surface hugs your skin with a light, uniform touch that soon becomes almost imperceptible. You bend and stretch and feel no restraint, no pressure points. When you rub your fingers together they feel sensitive, as if bare—but somehow slightly thicker. What is more, you feel just as comfortable when you step out into the vacuum of space."

The backpack would contain a mini-ecosystem based on "nanorobots," absorbing sunlight in space and producing a limitless flow of fresh oxygen from the carbon dioxide you exhale.

That is, if the robots can be shrunk to the size of living cells.

Drexler is a Stanford University engineer, futurist and author of *Engines of Creation,* in which he outlines a revolutionary future era of molecular engineering. He envisions that the current era of microtechnology, with transistors and components a few millionths of a meter in size, will give way to an age of nanotechnology, in which the dimensions are measured in billionths of a meter.

Nanotechnology means more than ultra-tininess, however. It would allow engineers to create objects in which each atom would be a distinct building block.

Nanocomputers are at the top of Drexler's wish list. They would not be electronic, since transistors and circuit elements don't work at atomic sizes. Instead, Drexler proposes to use "rod logic." The rods would be made of carbon, a few atoms wide, and would be pushed or pulled to represent the digits 0 and 1, the basic units of computer operation. The result, he concludes, would be a computer as fast and as powerful as a modern mainframe system, yet able to fit in a cube a few microns on each side. Tens of billions of these nanocomputers would fill the volume of a teaspoon.

Given nanocomputers, Drexler goes on to apply them as brains for nanorobots. As for moving parts—motors, shafts, and the like—Drexler draws inspiration from the life of a cell. "My body is full of nanomachines," he declares. "Molecular motors driving bacteria within me. Linear or sliding motors within my muscle fibers." This same exquisite control of matter, atom by atom, would yield mechanisms that work like their cellular counterparts.

TROY THOMAS

Many of Drexler's nanorobots would take the form of "assemblers," able to take hold of individual atoms within a fluid medium and put them neatly into place within a molecular framework. Diamond fiber, light in weight and far stronger than steel, could therefore become a common material; the assemblers would fit together the necessary atoms as if they were Tinkertoys.

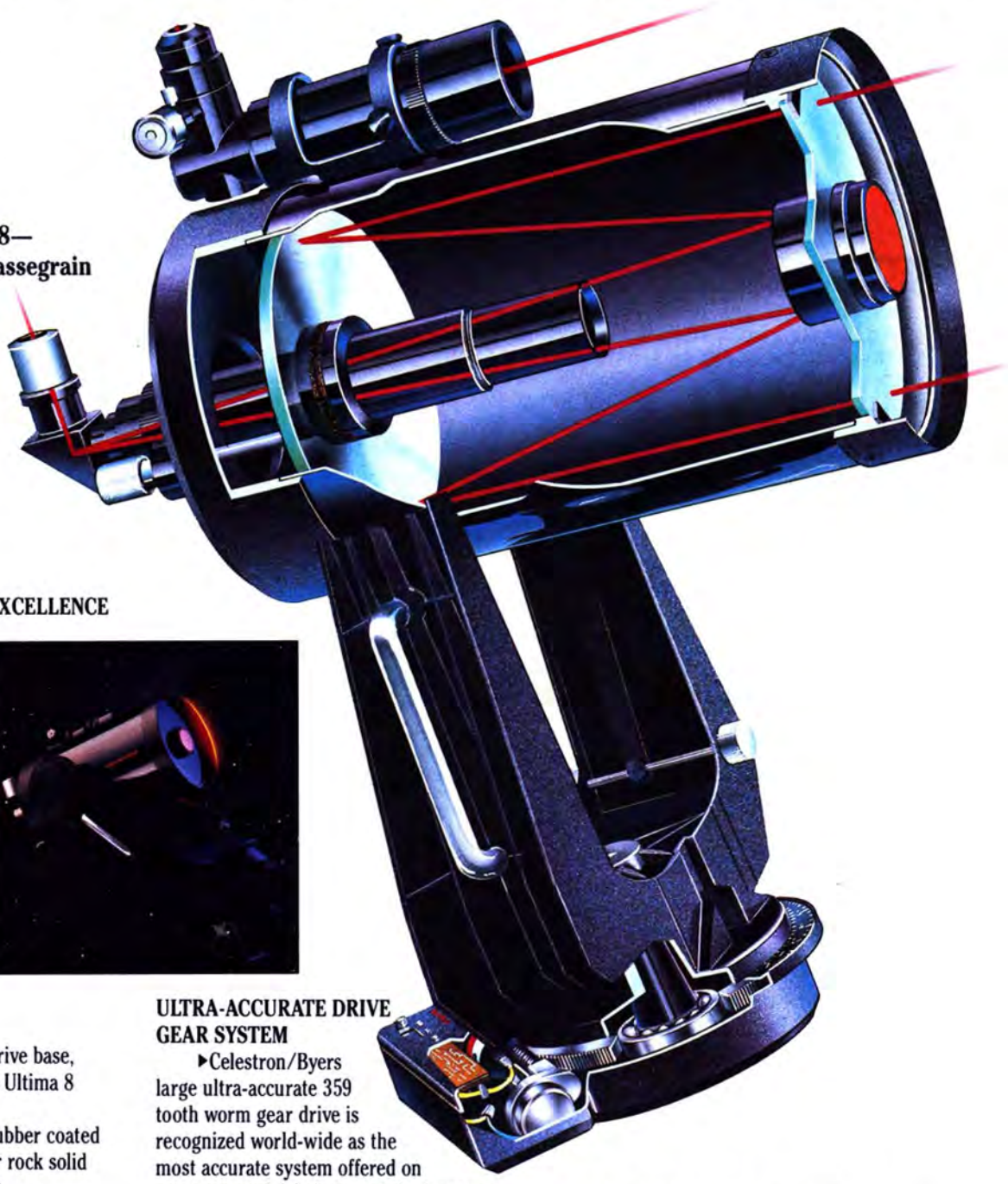
A master nanocomputer, acting like a fertilized ovum, could cause a large number of cell-like assemblers to link up to form a "body." It would have the shape of a specific large object—a rocket motor, for instance. Then, by extracting appropriate atoms from a succession of fluid baths, the array of assemblers would build the rocket out of diamond and sapphire. "It is a seamless thing, gemlike," Drexler has written. "Tap it, and it rings like a bell. Compared to a modern metal engine, this advanced engine has over ninety percent less mass."

Rockets, however, are already old hat in Drexler's thinking. For space propulsion, he puts his hopes in "lightsails," gossamer reflectors that would sail on the solar wind. "Imagine a network of graphite-fiber strands, a spinning spider web kilometers wide," he urges. "Picture the gaps bridged by reflecting panels built of aluminum foil thinner than a soap bubble. Now picture a load of cargo hanging from the web like a parachutist from a parachute."

How close are we to such visions? So far, nanorobots exist only in the realm of the theoretically possible. At Bell Labs, one group of scientists has shown that it is possible to manipulate single atoms, or small groups of atoms, dropping them into place upon a surface. At Carnegie-Mellon University, the chemist Robert Birge has devised molecules that change their shape, flexing like a movable arm when exposed to light of the proper wavelength.

Similar molecules might serve as grabbers, taking hold of atoms and then inserting them into place. Such experiments represent no more than the bare beginnings of nanotechnology. But Drexler is undaunted by the challenge. These early efforts, he says, "might give us tools with which to build the tools," with which to pursue his vision. □

BETTER FROM THE INSIDE OUT



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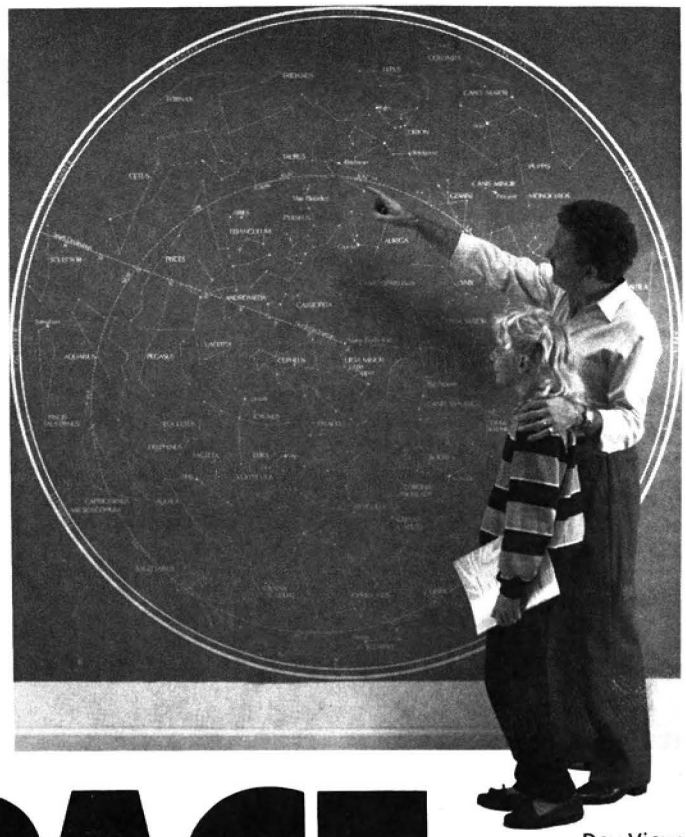

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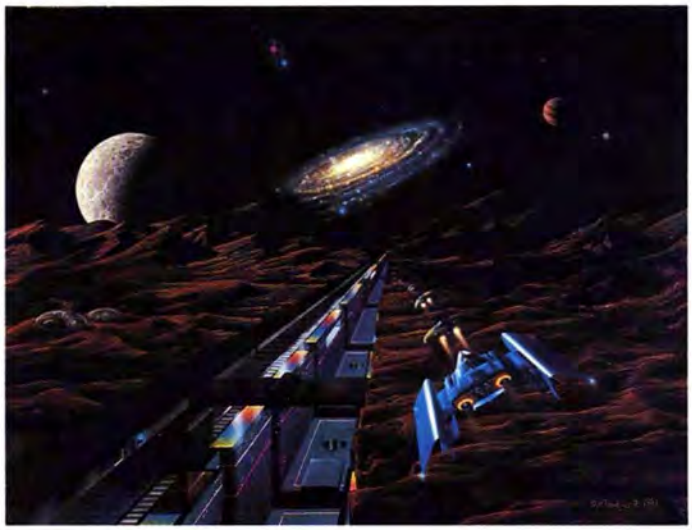

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Slow dancing
with a Martian moon
By Vyacheslav Kovtunenko

Next Stop, Phobos

The last time we paid a visit to Mars, two U.S. Viking probes sent back the first historic photos from the planet's rocky surface. Now, more than 12 years later, a Soviet spacecraft called Fobos 2 has returned to rendezvous with—and land on—one of Mars' tiny moons ("Mission to Phobos," June 1988). Most of the action is scheduled for late April.

FINAL FRONTIER asked the Soviet technical director for the Fobos project, Vyacheslav Kovtunenko, for a status report on the mission and a preview of things to come. At the time we went to press, minor problems with Fobos 2's television cameras and data collection system were not expected to jeopardize the success of the mission.

– Editor

Several years ago, at the peak of the program to study Venus and Halley's Comet known as project VEGA, the Soviet Union invited the international scientific community to take part in a still more complicated expedition to Mars. The project that resulted—called "Fobos"—involves Soviet specialists working together with scientists from 11 European countries, as well as representatives of the European Space Agency.

A mobile probe, or "hopper," will bounce from place to place on the tiny moon, analyzing the soil as it goes.

Two unmanned interplanetary spacecraft, Fobos 1 and Fobos 2, were launched from the Baikonur Cosmodrome last July on a 200- day flight to Mars. The expedition uses the first in a new class of "intellectual" space robots capable of observing large sections of the surfaces of celestial objects, while observing comparatively small areas in minute detail.

This new class of probes is particularly convenient for studying small bodies like Phobos, which have weak gravitational fields. Fobos is capable of closing in on an object and performing complicated maneuvers over its surface, using only information from the spacecraft's own onboard facilities and television system.

The initial stage of the flight of both spacecraft passed successfully. On July 16 and 21, scheduled trajectory corrections were carried out. In August, ground tracking stations at Yevpatoria, Ussuriysk, and other places started receiving scientific data.

The long transit to Mars provided opportunities to study the Sun in the x-ray, ultraviolet and optical ranges, and to determine the composition of the

continued on page 62

▼ ▼ ▼

Forget the politics.
Forget who's ahead.
What's the best way
to get there?
By Tony Reichhardt

Roads to Mars

It's snowing like a bear in Chicago. Thousands of stranded travelers are spending the last miserable moments of their Christmas vacation drooped in the lobby chairs at O'Hare airport, wanting nothing more than to get home. And in the nearby suburb of Schaumburg, John Soldner is trying to get to Mars.

He points to a computer printout, like a ticket agent routing me through Cleveland. This particular flight—an opposition-class trajectory leaving Earth in November 2004—looks pretty good in terms of price and travel times. A flyby of Venus on the way out. Thirty-day layover at Mars. There's an advance purchase required, though: about 15 years of steady funding.

If you don't care to *stop* at Mars, Soldner can offer you a round-trip flyby in 2003 that would take only 12 months. You say humans aren't up to such a long and perilous voyage? Last December, two Soviet cosmonauts returned to Earth—healthy and happy, by all accounts—after a full year in orbit.

For the first time in history, a human expedition to Mars is within hailing distance. In fact, we're probably closer to the first Mars journey than to the last landing on the Moon.

We've been heading there for decades, of course. The first to do the practical calculations was Walter Hohmann, architect for the German city of Essen-on-the-Ruhr, who in 1925 described a way to reach Mars—or any other planet—using the least possible amount of energy.

Interplanetary travel, Hohmann knew, is a game of moving targets. Earth, Mars and a spacecraft all orbit the Sun at different speeds, so our craft needs to meet up with Mars at the right moment in its perpetual race around the Sun. If we nudge the spacecraft with enough rocket thrust, it will break out from Earth's orbit into a wider ellipse around the Sun. That lazy, arcing path eventually grazes up against Mars' orbit when the Red Planet is on the opposite side of the Sun from Earth—an alignment known as conjunction.

With these "conjunction-class" orbits, the typical round-trip to Mars takes three years. About a year is spent exploring the Martian surface, before the planets are again aligned in such a way as to make the return trip economical.

Until recently, Hohmann's route was about the best we could do using ordinary rocket vehicles. When Wernher Von Braun published the first blueprints for a Mars expedition in 1952, he sent his flotilla of ten vessels and seventy people on a Hohmann trajectory. The

"Marsprojekt," dreamed up in the deserts of Texas and New Mexico where Von Braun was testing rockets after World War 2, was remarkable for many things, including its identification of the human problems that still plague Mars planners today—the effects of weightlessness, radiation and even the "spiritual hardships" of long-term spaceflight.

In the mid-1960s, while Von Braun was still building his giant Saturn 5 vehicle to carry the first astronauts to the Moon, NASA was actively considering sending humans to Mars as a follow up. As many as 60 contractors worked on the mission designs, with plans to reach Mars before the end of the 1980s. There is little doubt we'd have been there by now if the funding had continued.

But by 1972, the post-Apollo, post-Vietnam depression had set in, and the nation turned its back on human exploration beyond Earth. Instead, NASA focused on building a reusable space plane for reaching orbit. Official talk about Mars expeditions was driven underground, and the faithful—including many from NASA—were forced to meet like Christians in the catacombs at a series of "Case for Mars" conferences held in Colorado.

In the soul-searching that gripped NASA following the Challenger accident in 1986, the agency's thoughts once again turned toward human trips to the Moon and Mars. Under contract to a NASA task force headed by astronaut Sally Ride, John Niehoff—John Soldner's boss at Science Applications International Corporation (SAIC) in Chicago—developed the "split/sprint" trajectory that has changed our way of thinking about voyages to Mars.

A similar concept had been worked out almost simultaneously by a group of students at the University of Texas, but it was the Ride report that brought the revolutionary split/sprint mission into the mainstream of NASA thinking.

Niehoff's approach is surprisingly simple. First, anything that isn't necessary for the Mars-bound leg of the journey is sent ahead on a slow, conjunction-class trajectory, to be parked in Mars orbit. This includes the vehicles (and fuel) that would take the crew down to the Martian surface and back up to orbit, as well as whatever fuel and supplies would be needed for the journey home.

The long road: A Moonbase could be either a valuable steppingstone or an unnecessary detour on the way to Mars.

The crew wouldn't leave Earth until the cargo ship had reached Martian orbit safely. Only then would they be launched on a high-energy path that would get them to Mars (in the case of the November 2004 opportunity) in only seven and a half months. Upon arrival, an "aerobrake" shield would slow the speeding spacecraft, using drag from the thin Martian atmosphere to bleed off energy. Aerobraking is vital to the split/sprint concept, because it reduces the need to carry heavy retrorockets and fuel to slow down at Mars.

The crew would spend about 30 days at Mars—20 days exploring the surface—before they would have to return to Mars orbit, fuel up their return vehicle from tanks sent ahead on the cargo craft, and head for home while the planets were still properly aligned.

The trip back to Earth is also a high-energy trajectory. In fact, it can take less time than the outbound voyage—only five and a half months for the 2004 case. ("Sally Ride really liked that short trip home," says Niehoff). Total round-trip: only 14 months. And that's using plain, old chemical propulsion—the same technology that has launched everything from John Glenn's Mercury capsule to today's space shuttle by burning liquid fuel in the presence of oxygen.

Niehoff and his SAIC team figure 14 months is about as good as we can do given the current ground rules. You could get there faster, but you'd need to haul prohibitive amounts of fuel into Earth orbit—still the most expensive part of the whole journey. You can stay longer on the surface of Mars—60 days in one scenario—but that drives the round trip up to 20 months.

Finding a technological shortcut to Mars is not the same as having a strategy, however. That's why, for the first time in 20 years, NASA is now studying the larger question of how—and when—this nation might dare to send its first human expedition to another planet.

Frank Martin, head of the space agency's new Office of Exploration, is careful to point out that the "case studies" currently underway are not actual mission designs. They're simply exercises, a way to test different options and approaches to the broad problem of "expanding human presence and activity into the Solar System."

Last year's four hypothetical scenarios included a split/sprint expedition of four people to the Martian moon Phobos in 2003; a series of three missions to Mars, beginning with an eight-person voyage in 2006; an observatory on the Moon; and a more involved lunar base that would be a stepping stone for the first Mars journey, which would happen sometime around 2010.

The three Mars-related scenarios show the wide range of thinking on which is the best approach to the Red Planet. Each road has its advocates. The Phobos option traces its heritage to S. Fred Singer, now the chief scientist at the U.S. Department of Transportation and one of the key strategists behind the launch of the first Earth satellite in the 1950s. Singer introduced his "PhD"—Phobos-Deimos—concept in 1978 as a quick and practical first voyage to Mars.

Instead of sending the first crew to

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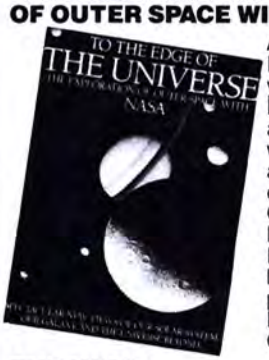

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the Martian surface, which requires heavy, expensive vehicles to land on the surface and then fight the planet's gravity back up to orbit again, astronauts would stop at one of the tiny Martian moons, where the gravity is extremely low. (It's actually as easy to reach Phobos as it is to land on our own much closer Moon, in terms of the amount of energy required.) From Martian orbit, the humans could "drive" robot rovers that would explore the planet below, without the annoying 20-minute time delay that tele-operators on Earth would face.

The Martian moons are more than convenient platforms in orbit, however. Scientists believe they contain water and other resources that could be used to produce rocket fuel, oxygen and other supplies for future expeditions.

Singer argues that "a mission to Phobos and Deimos is not only easier and cheaper by far, but scientifically more valuable than landing people on Mars itself."

NASA isn't ready to go that far, but the agency is clearly interested in the Phobos option. Last year's case study found the idea to be "promising," and one of this year's exercises includes a PhD mission as the first in a series of four Mars expeditions from 2004 to 2011. A Phobos flight might even eliminate the need for an earlier automated sample-return mission—the PhD astronauts would simply bring back samples gathered by their tele-operated robots.

Not everyone is enthusiastic about traveling 40 million miles to Mars, at a price tag of tens of billions of dollars, only to stop a few thousand miles from the surface. Harrison Schmitt, the last Apollo astronaut to step on the Moon and a former U.S. Senator from New Mexico, calls the plan "stupid," a stalling maneuver. NASA's Frank Martin says even he took some convincing to see the idea's merits.

But Kerry Nock of the Jet Propulsion Laboratory, who has designed Mars missions for NASA, thinks it's a "damn good idea," particularly for its development of resources that could be used for future missions. NASA has started calling Phobos a "gateway" to more advanced exploration of the Mars system.

A similar argument rages over the "Mars-by-way-of-the-Moon" approach. Paul Keaton of the Los Alamos National Laboratories, who directed a comprehensive study of Mars exploration options in a joint project with NASA in 1985, strongly favors using a lunar base as a testing ground before committing to Mars. On the Moon, Keaton says, we could learn how to protect ourselves from radiation, how to live in reduced gravity, and how to operate hardware for long periods in space. In one of NASA's 1988 case studies, fuel produced on the Moon is used to cut the cost of transportation to Mars. The first Martian expedition doesn't reach the planet until after 2010, but it's able to stay for a year or more when it gets there.

Again, the jury is divided. Carl Sagan, a vocal Mars supporter, calls a Moon base an "unnecessary detour" if we're heading for Mars. Apollo 11 astronaut Mike Collins, who chaired a task force on NASA goals in 1987, says the agency needs one major goal, not two. His choice would be Mars.

Most experts agree with Collins that Mars is our ultimate destination. Whether we should take an expeditionary approach or a slow, *evolutionary* one is the issue. There is a strong desire, pervasive in the space "community," to avoid the experience of Apollo—an expensive crash program that was followed by years of virtual stagnation. Many "evolutionists" get nervous when you start talking about galloping to Mars. This time, they say, we should build political longevity into the program, plant roots that can't be pulled up easily—even if it means deferring the first trip.

That's precisely why some evolutionists don't like the idea of a "sprint" mission at all. Even John Niehoff, whose work has gone a long way toward making a quick, Apollo-style Mars mission practical, believes that a race to plant "flags and footprints" on Mars, with no plans for a follow-up, would be "threatening to an orderly program."

NASA's Office of Exploration clings stubbornly to this long view as well. Frank Martin believes we can have it all—the Moon *and* Mars—without breaking the federal bank. But he, Niehoff and others believe it's of paramount importance to keep NASA's year-to-year budget requests relatively constant, with no huge "peaks" in funding that might make a tempting target for budget-cutters, like a soldier's head sticking above a trench.

Some of the pressure for a sprint to Mars has come, surprisingly, from above. Searching for an exciting mission to catch the fancy of a new President, NASA Administrator James Fletcher last year asked his Office of Exploration to determine how quickly the United States could land on Mars, given the political mandate to do so.

One of the options now under study is just such a crash program. Having learned last year that sending eight people to Mars can be prohibitively expensive, the 1989 "mission" throws off some ballast. The crew has been cut down to three people, two of whom would land on Mars, Apollo-style. There are no heavy rover vehicles, and precious little science equipment onboard. Just a landing, 20 days on the surface, and back to Earth.

Neither this "lean and mean" Mars landing nor a sprint to Phobos assume the need for a space station in Earth orbit to assemble and fuel the Mars

The back road: Visiting the moons of Mars first may open a "gateway" for future expeditions to the surface. It's cheaper, too.

ships. But NASA planners—and most other experts—agree that a space station of some kind is a crucial step on the road to Mars. It would provide long-term operational experience in space, and perhaps most important of all, a place to study human adaptation to long-term weightlessness.

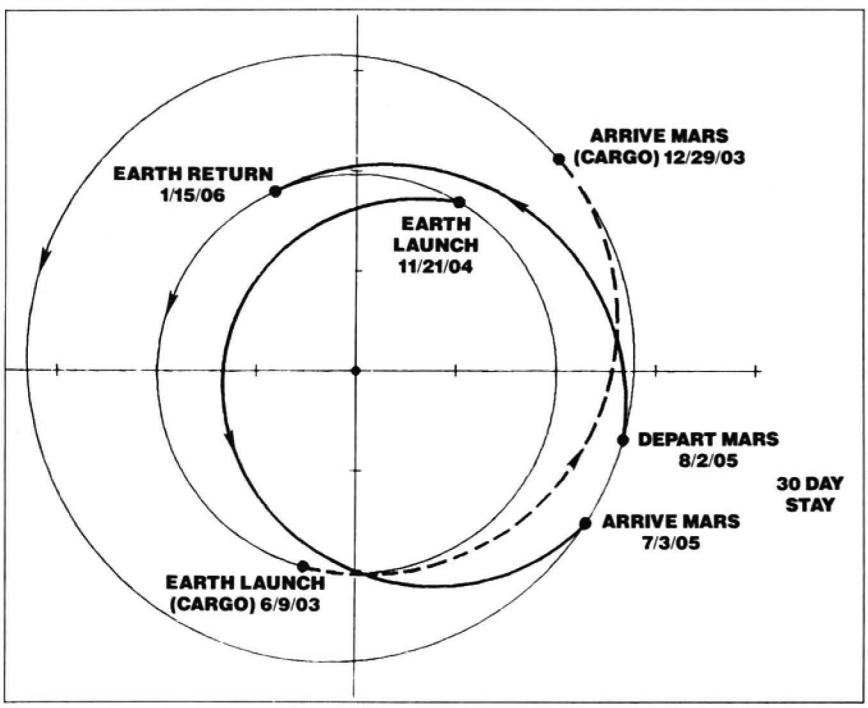
If a Mars ship were built, fueled and waiting in orbit tomorrow, we probably wouldn't get onboard. The reason? Uncertainties about the crew's health and performance. NASA biomedical experts are unwilling to commit to stays in space much beyond the three-month U.S. record established by Skylab astronauts in the 1970s.

gent muscle-toning exercise program in space.

Would astronauts simply need to wait inside their Mars lander for two days before stepping out onto a world where the gravity is only one-third that of Earth? We don't yet know.

This human "problem" provides even more incentive to find an express route to Mars. And if we're *really* serious about limiting the time spent in zero-g flight, we should probably think beyond the current chemical-powered rockets to some form of advanced propulsion, even for the first expedition.

The idea of "atomic drive," as the science fiction stories used to call it, is not



SCIENCE APPLICATIONS INTERNATIONAL

One possible "split/sprint" mission sends the heavy cargo ship ahead to Mars on a slow trajectory. The crew follows behind—taking a faster "sprint" route—more than a year later.

The Soviets, however, are more experienced at long-term spaceflight. A dozen cosmonauts have stayed in space for six months at a time—enough for some one-way sprint trips to Mars. While long-duration crews generally are wobbly for the first few days after returning to Earth, some have shown a remarkable ability to readapt to gravity. Following his eight-month orbital stay in 1984, Oleg Atkov told Carl Sagan that he could walk "a thousand steps along the center line of a highway." The 12-month record holders, Vladimir Titov and Moussa Manarov, reportedly were able to walk unassisted within 48 hours of their return to Earth last year, due to a dili-

new. In 1952, Von Braun considered using it for his "Marsprojekt" expedition, but decided that the economical use of nuclear power for rocket propulsion was still too far in the future. More recently, political and environmental issues associated with nuclear power have banished "atomic drive" from mainstream thinking about missions to Mars.

Not so in the 1960s, however. On May 25, 1961, in the same speech that included his call to reach the Moon by decade's end, John F. Kennedy told Congress of plans to develop a nuclear rocket that would "give promise of some day providing a means for even more exciting and ambitious exploration of space." Mars missions designed by NASA contractors before 1967 routinely made use of nuclear-powered engines for some part of the journey.

Using Kennedy's funds and drawing on earlier research done at Los Alamos, NASA even built a working prototype of a Nuclear Engine for Rocket Vehicle Applications (NERVA). By 1969, a dozen "breadboard" test engines had been successfully fired. But in 1972, budget cuts forced the space agency to drop all its plans for interplanetary travel, and NERVA was left without a mission. The program was scrapped.

With the near disaster at Three Mile Island and the growth of the environmental movement in the 1970s, *anything* nuclear fell out of favor. By the time of the first "Case for Mars" conference in 1981, says former JPL engineer Jim French, "we consciously decided not to consider big nuclear engines, because we didn't figure there was a snowball's chance in hell that we'd ever be allowed to develop them."

Even though the political sensitivity question is far from settled, NASA is once again playing with the idea of nuclear engines. The agency's Lewis Research Center in Cleveland is now studying a wide range of advanced propulsion concepts, from solar sails to engines that would burn oxygen combined with aluminum mined on the Moon. Some of the engineers who worked on NERVA in the 1960s have even been called in for workshop meetings.

The advantage of a NERVA-type nuclear engine—which heats up hydrogen to high exhaust velocities by running it through a uranium reactor—is that it's about twice as fuel-efficient as ordinary chemical rockets. For a split/sprint mission, nuclear engines might not shorten the trip time; they would more likely be used to reduce the fuel load, and therefore the weight and cost of a Mars flight.

If a NERVA-type program were started up today, estimates range from five to ten years before a working vehicle could be produced. Few experts think there would be any problem—other than political—in being ready for a Mars flight in 2003 or 2004.

There are still technical issues to be addressed, however. The crew would need to be shielded or kept at a distance from the onboard reactor, and nuclear rockets aren't as easy to start and stop as more conventional

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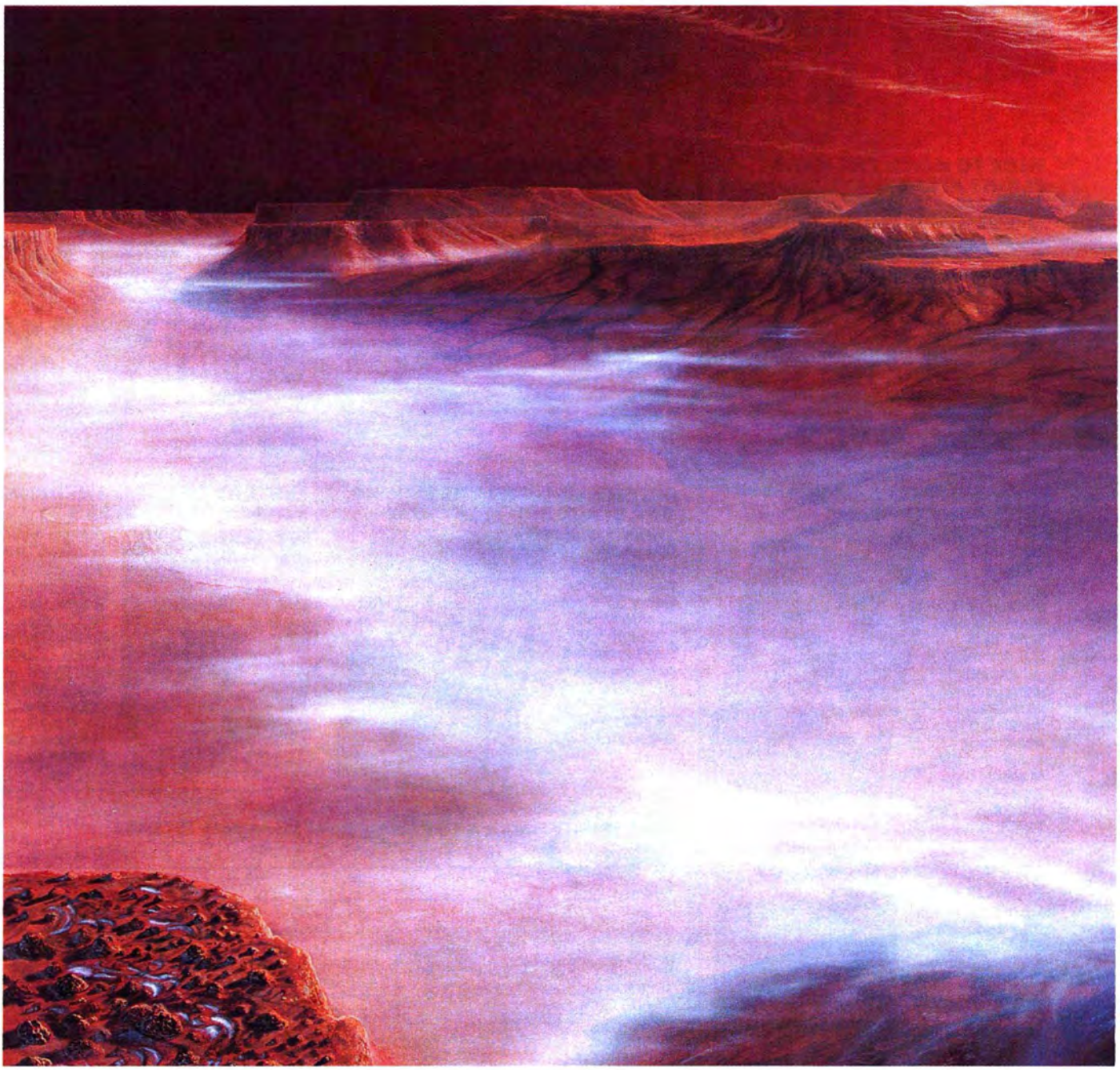
Landing on Mars is one thing. Staying is another.

By Robert M. Powers

Being There



We have fantasized for years about that moment, sometime near the dawn of the next century, when the first ribbed boot drops down before the TV cameras on the red soil of Mars.

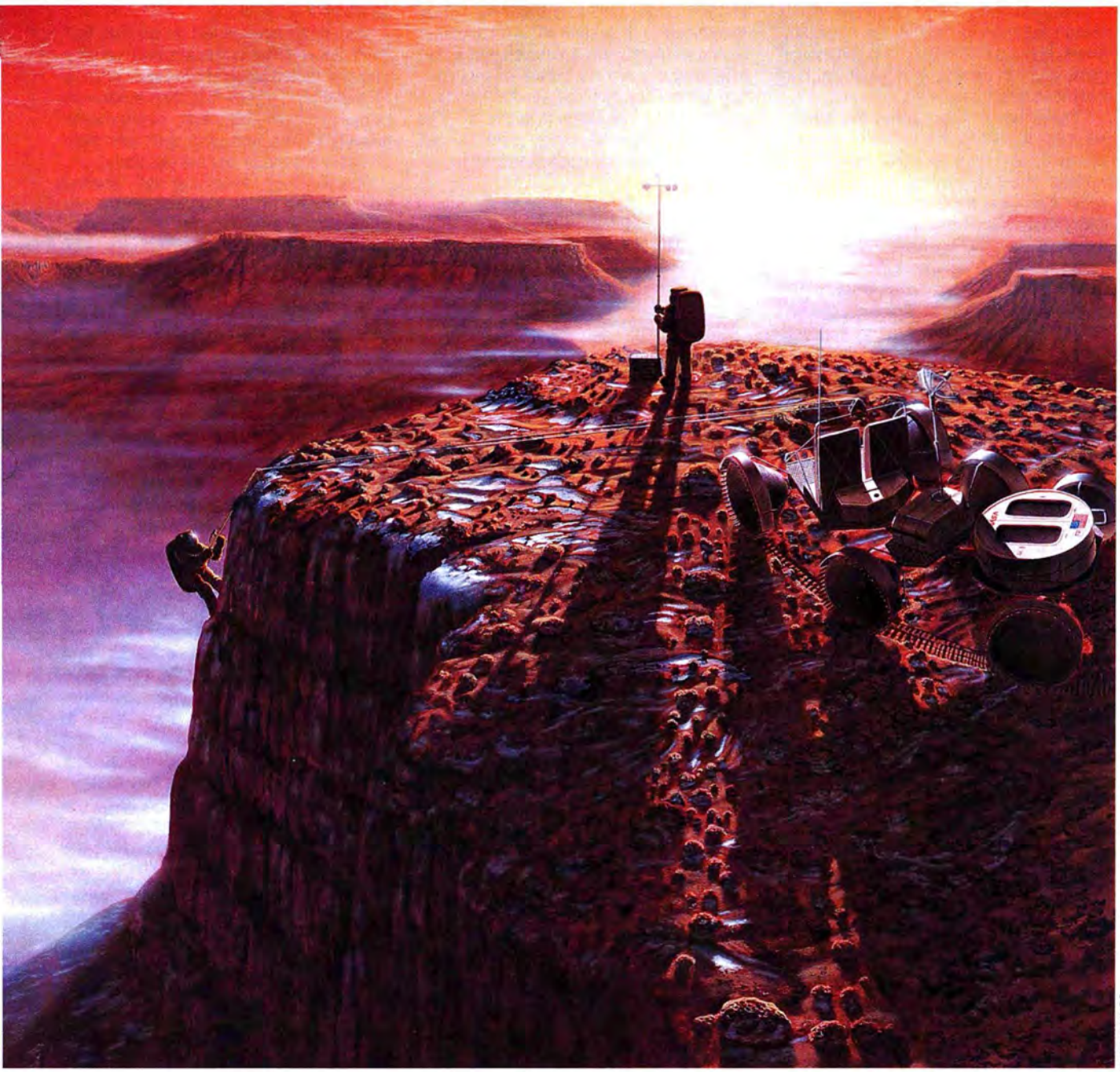
And what then?

We have failed so far to realize one of the most precious of human dreams: to *live* on another planet, not just land there and leave again. The most interesting thing about our "progress" (if we can call it that) toward that goal is that the task becomes cheaper and safer the more we think about it. Knowing that even the *first* Mars mission will be a massive, extremely expensive undertaking, experts have begun to think imaginatively, looking at inexpensive options for staying on Mars and wringing the last drop of potential from the computers.

Nowhere is this attitude more evident than in the current plans for setting up permanent bases, even cities, on the Red Planet. The first ingredient in the "new" thinking is to produce rocket fuel on Mars for the return trip to Earth. Cost savings for this on-site propellant production would be enormous, since none of the fuel to get back has to be produced on Earth or carried all the way to Mars.

There are problems with the concept, however: it has to work perfectly, it requires power and the range of possible rocket fuels is limited by the known Martian resources. Liquid oxygen and liquid carbon monoxide top the list of possible propellants. The LOX/CO combination is readily available on Mars (just compress the atmosphere), and the technology for liquefying the fuels and storing them is already well known. They aren't the most efficient fuels, but in the relatively weak Martian gravity, their performance might compare with that of more conventional Earthly fuels.

Using industrial processes common on Earth, it may be easier to manufacture a more efficient fuel from oxygen and methane. But the process requires a great deal of water—and considerable effort may be required to get



PAT RAWLINGS

at the available water on Mars. Still, the bottom line is that a small plant weighing only a few tons and using a small nuclear reactor for power could produce 100 tons of fuel while consuming just a few hundred pounds of raw material a day.

In 1988, the University of Arizona/NASA Center for Utilization of Local Resources was established by the space agency as one of nine nationwide centers looking at strategies for exploring the Solar System. The center is so new that no one has yet come up with a satisfactory acronym for the place (John Lewis, the science principal investigator says, "It always comes out too big a mouthful to say no matter how you cut it.")

Last year Lewis' center received half a million dollars from NASA; funding increases to $1.2 million in 1989, then goes as high as $1.8 million for each of the three years following.

"The unusual thing about the study," he says, "is that NASA, unlike their usual practice, did *not* specify what they wanted. Instead, they let the universities write their own proposals. The second thing that was pretty unusual was that the proposals did *not* have to have 'payoff engineering' right away."

Not all of the center's work deals exclusively with Mars. "We are concentrating on three major areas," explains Lewis. "The first is the Moon, because there's a lot of work we can do on the Moon, and all of it—or at least a good part of it—can have applications to other bodies." The Arizona researchers also will take a look at using resources on the smaller bodies of the Solar System, including asteroids and the Martian moons, which don't require much energy to visit.

"When we get through with all that, we will concentrate on the problems of resources on Mars, hoping that we know a little more from the Russian mission [to Phobos], or even one of our own unmanned missions," says Lewis.

Lewis believes the first order of business for Mars is to study methods of fuel production: "For example, is it better to get water from the atmosphere or from the soil? We think we already know the answer to that one—it is easier to melt ice than to extract water from a very dry atmosphere. But more study won't hurt.

"We want actually to develop the technology of propellant extraction, not just talk about it," he continues, "because that's the road to Mars, we think. Why use the space shuttle at $6,000 a pound to launch stuff we could manufacture for a few cents a pound on Mars?"

Lewis even talks about establishing a propellant factory on Mars *before* the first human explorers ever leave Earth. He points out that one goal of the Arizona center is to find a method that would allow us to send a small, unmanned spacecraft to Mars, and have the automated laboratory or factory begin producing and storing the fuel long in advance of the main mission. "Now *that*," Lewis exclaims, "would make a mission to Mars or anywhere else a *real* possibility."

"The costs of a Mars mission using the automated propellant production concept," he continues, "are probably a bit too low for NASA. They like things big and complex. Still, we're tremendously excited by what we think we're going to come up with."

After the economics of fuel production are mastered, says Lewis, Martian settlers could turn to other indigenous resources to decrease their reliance on supplies from Earth. He notes that some new ideas have surfaced in the past few years: ferrous metals for building construction on Mars (the planet has plenty of iron—it's rusty), glass bricks, concrete and various ceramics for construction.

"Why use the space shuttle at $6,000 a pound to launch stuff we could manufacture for a few cents a pound on Mars?"

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"I think some of the experimenting with *wet* concrete on lunar samples has been pretty dumb," Lewis says. "We're looking at dry concrete bonding processes. On Phobos and Deimos, assuming their compositions are what we presently think, you have calcium carbonate. If you bake it, you can get lime and water for concrete. On the Martian surface you have permafrost, at least north and south of 30 degrees latitude, and every clay mineral known."

When it comes to living off the Martian land, Lewis is fond of pointing out that some of the concepts from the 1950s were a lot closer to reality than those of the past 20 years. "We need," he says, "to look back at some of those ideas. So much of the newest stuff is concentrated on propulsion and precursor missions, and the Phobos-Deimos options, that we are only now getting serious about living and working in the Martian environment."

For example, most everyone thinks iron is easy to come by on Mars, but that doesn't mean wrought-iron patio furniture will be *de rigueur* for Martian bases. "More likely," says Lewis, "you might have furniture of ceramic fibers—rods of organic polymer matrix. But even the ceramic fiber furniture may not be the way to go. You can get carbon from the atmosphere and make carbon fibers. And that, plus hydrogen from water, can produce plastics and polymers eventually."

Martian "cars"—or at least air transport—may use the same fuel used for the flights to and from Earth. It's fairly easy to imagine an internal combustion engine running on liquid oxygen and liquid carbon dioxide. Taking the on-site fuel plant concept a step further, that same car or airplane might carry a 100-pound processor that "breathes" in the atmosphere and puts out fuel for the tanks as it goes along.

"You don't even need to go that far," says Lewis. "There have been several designs for a hydrogen peroxide engine of sorts; and there is some evidence, primarily from the soil experiments aboard Viking, that hydrogen peroxide on Mars probably occurs naturally."

The Martian "shopping list" doesn't stop with the ubiquitous iron and water or with the carbon dioxide atmosphere. We are fairly certain, for example, that there is sulfur on Mars. Here on Earth, we use 100 billion pounds of sulfur a year—in explosives, insecticides and fungicides, and in the manufacture of acids, dyes, detergents and steel.

The expected abundance of sulfur on Mars, and some other elements, leads to the conclusion that phosphorous is there, as well as zinc and lead. Magnesium chloride is a possible ingredient of Martian salts, and from that we could make pure magnesium metal, which might be a useful building material in the weak Martian gravity.

The first "city" on Mars may look a bit like a toy construction of cylinders, built mostly underground. It will have some wonderful advantages over a city on Earth: no rain, sleet or snow, and regrettably no postman to defy them (thanks to electronic mail). Neither floods nor mudslides are expected in the current Martian geological era, and Marsquakes are rare and not strong, according to our present information. Natural erosion of buildings is nil—if you build your adobe house on Mars using magnesium beams for the *"vigas,"* you don't have to stucco it—and there is little corrosion of metals.

The biggest weather problem will be Martian dust storms, some of which can be pretty fierce. And just to give the scene some Earth-like qualities (underneath the slightly disgusting pink sky), an occasional early morning frost will rest on the antennas and exposed sur-

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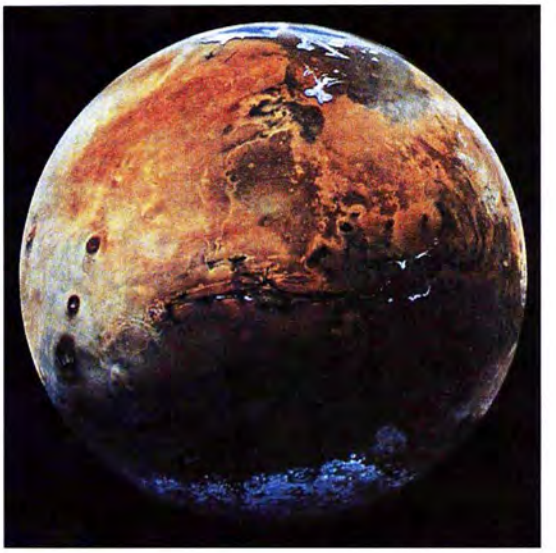

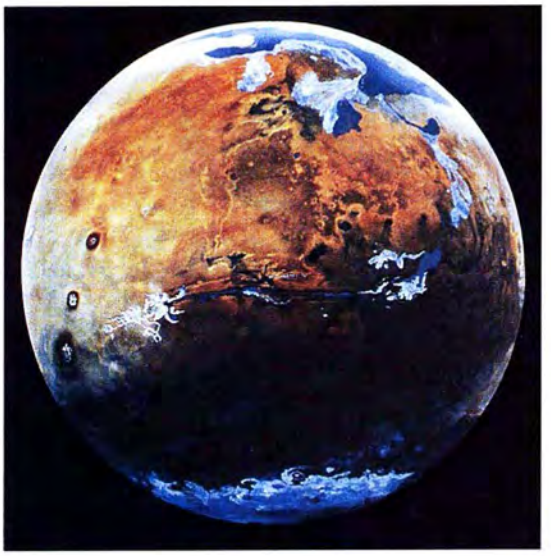

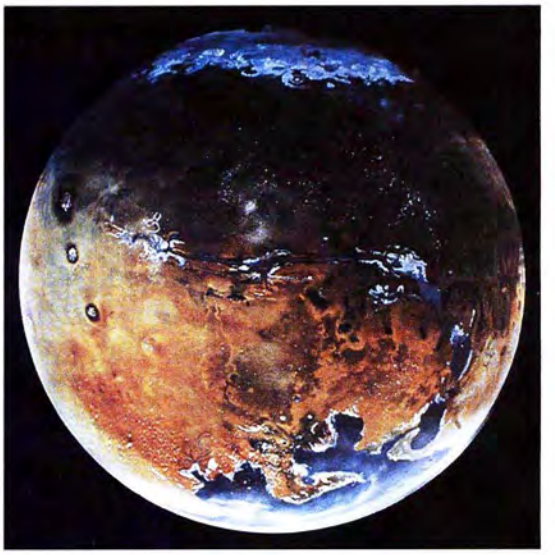

MICHAEL CARROLL

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The ultimate in home remodeling

By Alcestis R. Oberg

In Earth's Image

The idea of terraforming—engineering a planet to sustain human life—has a lineage as old as humanity itself. The first terraformers were cave dwellers. Finding their world too cold, they deliberately altered the environment to suit their comfort by building fires. Since then, we human beings have been tireless planetary engineers—we drain swamps, irrigate arid places, clear jungles, create land fills and otherwise rearrange the natural order of creation.

It used to be that the notion of terraforming *other* pieces of real estate in the Solar System was confined to the realm of science fiction. The first serious attempt to formulate an approach to planetary engineering came from Robert MacElroy and Maurice Averner, two scientists at NASA's Ames Research Center, who wrote a technical book in 1976 called *On The Habitability of Mars: An Approach to Planetary Ecosynthesis.* In the last ten years or so, a handful of seminal thinkers has taken the old half-baked ideas and realistically, systematically put them up against our new understanding of the planets. Terraforming is no longer fantasy; it's now discussed seriously in the context of geophysics, atmospheric science, biology and even ethics.

Not surprisingly, Mars has the greatest allure for would-be terraformers. It isn't completely alien like the outer planets, and it already has a big reservoir of useful resources—including water, trapped as subsurface frost and in ice caps at the Martian poles. Among the suggestions for freeing this water have been to use enormous orbiting mirrors to melt the icecaps, or to sprinkle black carbon over large areas of the planet to increase the absorption of sunlight.

In *New Earths*, his popular book on terraforming published in 1981, author Jim Oberg theorized that additional water could be imported from Saturn's icy outer moons, and that asteroids could be impacted onto the Martian surface to create warm craters. In the new Mars oases, existing water and air would gather naturally. In time the first rain would fall on a thirsty planet, the scent of dampness would fill the thin air, and the first rainbow would arch in the sky.

Oberg, however, is an aerospace engineer, so his scenarios are dominated by grand technological solutions to planetary problems. In the decade since the first scientific meeting on terraforming was held in 1979, people from other backgrounds have wondered if manipulation of native materials—rather than cosmic engineering—wouldn't work just as well.

At the "Terraforming II" conference held at the Lunar-Planetary Institute in

Houston in March 1987, Christopher McKay of NASA's Ames Research Center jokingly called his home-grown scenario a "nickel solution" to a Martian makeover, as compared to Oberg's million-dollar scheme. "If someone wants to bet a million dollars, he's joking," McKay teased, "But if someone bets you a nickel, you say, 'Ah, now you're serious.'"

Assuming that we want to give Mars an Earthlike nitrogen-oxygen atmosphere and liquid water on the surface, says McKay, we'd have to "melt the water, which is frozen, get oxygen by breaking up the carbon dioxide, and unlock nitrogen, which, if Mars has any, is in the form of nitrate."

According to McKay's calculations, it would take an enormous amount of power, and a little patience: If we could harness almost all the energy that falls on the Red Planet, it would take 200 years to warm its climate enough to get liquid water.

"That's the easy part," confesses McKay. "Creating the chemical changes that would generate the atmosphere would take a couple hundred thousand years." He suggests that we could nudge the process along by cheating just a bit and adding traces of four so-called "greenhouse" gases. "Everybody would have to use deodorant [with its fluorocarbon propellants] five times a day" to keep the greenhouse effect moving along, McKay jokes.

The gases break down over a few hundred years, so he recommends changing the "cocktail of gases" from time to time as the planet changes. Even then, McKay notes that the numbers show terraforming Mars is still "just *slightly* impossible" without importing resources from somewhere else.

Richard Vondrak came to a separate but similar conclusion about the Moon during a NASA conference on lunar bases held last year in Houston. Vondrak, now a manager at Lockheed's Space Science Laboratory, began his thinking about terraforming as a Rice University graduate student, while studying the effects of Apollo rocket exhaust on the Moon's almost nonexistent atmosphere.

"The primary source of the lunar atmosphere is the solar wind," says Vondrak. "Other possible sources... are materials released or weathered from the lunar surface, or gases released from the interior." The mere presence of human life on the Moon during each Apollo landing—with its engine exhaust, airlock venting and even spacesuit leakage—overwhelmed the tenuous local lunar atmosphere "for about a month," Vondrak calculates, until the solar wind cleared away all traces of the visit in the atmosphere.

"Probably the people who terraform Mars will be the Martians themselves, the people who will live and die in that environment."

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This type of pollution is generally viewed as a problem to be overcome, particularly by astronomers, who hope to take advantage of the Moon's pristine skies at a future lunar base. But Vondrak figures that "if someone wanted to *intentionally* create a lunar atmosphere and not inadvertently terraform it by means of pollution, the necessary gases could be obtained by vaporization of the lunar soil." We'd merely have to blast the oxygen out of the lunar dirt—with nuclear bombs. Unfortunately, it would require 10,000 times more megatonnage than the current U.S. arsenal now holds.

Importing the resources from elsewhere in the Solar System might be cheaper. Vondrak calculates that a "cometary nucleus of 50 miles radius could be used to supply the man-made atmosphere." Trouble is, there are no comets that size around—Halley's Comet was only 20 miles in diameter—and we would have to find some means of conducting a "round-up" to provide comets in sufficient numbers.

"It would be easier to haul over an 'iceteroid' from around Saturn," says Oberg, who never has been a fan of using restless and temperamental comets in his terraforming schemes. "Comets are too small, too unpredictable—and too beautiful."

Of all the terrestrial planets, Venus would present the greatest challenge for global engineers. It also has the least sympathy among planetary environmentalists. Nobody has rushed forward to protect Venus from the terraformers' bulldozer, as they have for the Moon and Mars—probably because it so resembles our own mythical concept of Hell.

Even the most determined terraformers agree that Venus is in need of intensive care. It's too hot, courtesy of a runaway greenhouse effect. The planet has too much atmosphere (carbon dioxide), too little water and a slow rotation rate.

During the first terraforming conference in 1979, planetologist Steve Welch suggested that the sulfuric acid in Venus' atmosphere plugs holes that might otherwise be vents for heat. He'd start his makeover of Venus with "biological tools to remove the sulfuric acid [which] could have major results in letting heat leak away from the planet."

Steve Gillett, a geologist at the Univer-

Is There Now, or Has There Ever Been...

Life on Mars? "I'm 'radically neutral' on the subject," says Penelope Boston, a former NASA scientist now in Boulder, Colorado. "But to have life on Mars, the atmosphere would have to be recycled, and there's no evidence of that."

If life existed under the surface, there would have been perfect biological recycling of materials, which is highly unlikely. "We might find fossils—or geochemical traces of past life," says Boston. "But there has been lots of intervening cosmic radiation since it was around, and it wouldn't be on the surface. I'd look below ancient lakebeds." There would be no way to resurrect life, however, even if you could reproduce the exact condition of Mars when it was alive. "If it's dead, it's dead," says Boston, "unless there are pockets of extant refugees somewhere."

Soviet scientists are still excited about finding life on Mars and seem unconvinced by the data returned by NASA's Viking landers in 1976. Even many American scientists agree that the Viking life-search results were unsatisfactory. Boston thinks that "we picked the wrong experiments and did them in the wrong place." Viking should have looked for growth, and probably should have landed at the poles.

Though environmentalists don't enjoy the prospect of humans importing asteroids and seeding the Martian surface with bacteria, Boston and most terraformers see the endeavor as an expression of life, a product of intelligence. "I value life, and living things," says Boston. "A planet with a biosphere is a lot more valuable than one without it.

"Probably the people who terraform Mars will be the Martians themselves, the people who will live and die in that environment, and will have some societal mandate to do it," Boston continues. "It will be an outgrowth of their survival. The people who will do it will be strong, because of a kind of natural selection process for human character that occurs in a New World."

sity of Nevada, attacks the problem by rehabilitating the atmosphere first. "The key to Venus is Mercury," he said at the 1987 conference. Gillett would use self-replicating robots to mine and refine Mercury's calcium and magnesium into pure ingots, which would be fired toward Venus by mass drivers. Magnesium and calcium are the oxygen-scavengers of the periodic table; they could shear off the overabundant oxygen from the carbon dioxide atmosphere and begin to create a more chemically useful biosphere.

The bottom line is energy, though. Gillett estimates that the total power involved in this operation equals about as much solar energy as Mercury receives in three years. "It's not totally preposterous," he admits, "but *almost* totally preposterous."

Despite all the ideas for altering a planet physically, the current thinking among terraformers is that water and a primitive atmosphere are not enough. The key factor in whether planets flourish or fizzle may be the presence of life itself.

Early microbial life probably played a crucial part in the creation of Earth's biosphere. If it is even partially true, as some theorists have proposed, that lifeforms regulate and maintain the biosphere within the narrow range of temperature and atmosphere suitable to themselves, life would have to be seeded on Mars in order to keep it from teetering back into static lifelessness.

In Colorado researcher Penelope Boston's scheme, terraforming would be done planet-wide, not just in oases or "dimples." Bacteria that don't require oxygen could start to "process" a protobiosphere in semi-protected areas on Mars—cracks and crevices on the surface, at the poles, or even under the surface. They would "find their own way and evolve while they were creating an atmosphere," says Boston. "Organisms could be specially developed through genetic engineering, or several organisms could work together that have desirable properties."

Because Mars has no magnetic fields, it receives much more solar radiation than does Earth. "There would be strong evolutionary pressure to select organisms that are immune to the effects of radiation, or which change in some positive way," says Boston. "Certainly there would be some mutation."

Boston notes that human reproductive systems are very susceptible, so even on a terraformed Mars we might not be as free-ranging as on Earth. Martian settlers may have to spend a good part of their time in radiation-protected abodes, "no matter how good the biosphere is." They'd have to look after food crops with care, and make sure the seed stock in certain crops is shielded from radiation.

Canadian biologist Robert Haynes argues that it might be more feasible to stop short of total terraforming than to go for an "in Earth's image or bust" scenario. The fabrication of a sustainable ecosystem on a currently lifeless, sterile planet, he suggests, may establish "a new arena in which biological evolution ultimately might proceed independent of further human husbandry." Fostering an environment on Mars that might nurture the growth of *any* biota, however exotic and strange, might be more within reach than true terraforming.

Just about everyone agrees that Mars won't be turned into another Earth anytime soon. Time scales for the planet's chemical and biological transformation run into the hundreds of thousands of years—not long in geological time, but almost unimaginable to the short-lived humans who would have to make it happen. Small oases could be created much sooner, though they would still be lengthy projects, along the lines of cathedral and pyramid building.

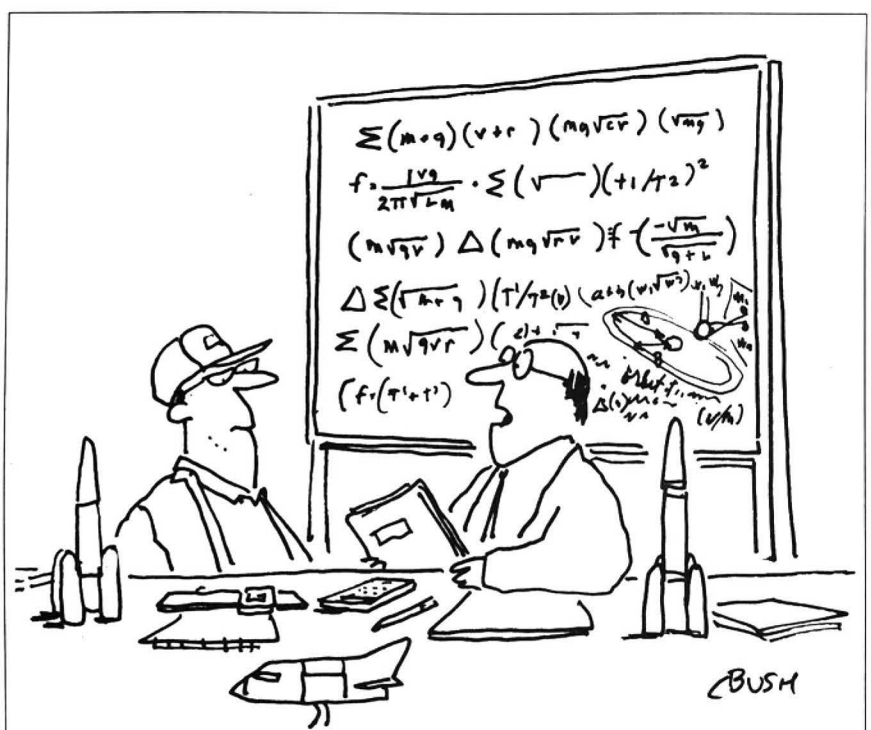
So why bother to think about terraforming at all? Some theorists say it's the intellectual challenge. "Comparative planetology forces scientists to rethink things they learned by rote," explains Penelope Boston. "It's intensely interdisciplinary, too."

Most important, it forces us to come to grips with how Earth's biosphere works. We still don't know how small a stable ecosystem can be and still function—whether it's a jar of algae and shrimp or a whole planet.

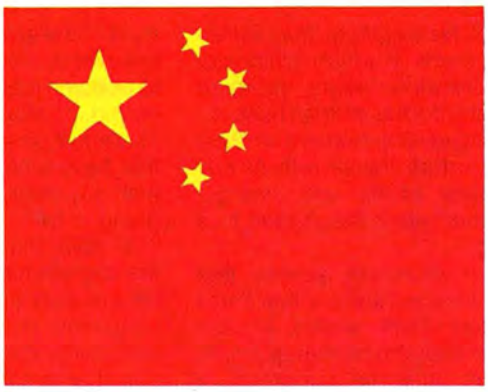
To Jim Oberg, it's even more urgent than that. "Mother Nature was a bitch to most of the species that ever inhabited this planet," he said. "Either we'll have to become masters of planetary engineering or victims of natural change. There are only two kinds of creatures that have inhabited this planet: those that are extinct and those that are going to be."

In 1988, the greenhouse effect and the depletion of ozone in Earth's atmosphere were the subject of newspaper headlines, not obscure doctoral dissertations. Global habitability moved out of scientific journals and into the nightly news. Not coincidentally, terraforming found its way into *New York Times* editorials, and even into speeches by NASA Administrator James Fletcher. The once-radical idea that terraforming is possible all of a sudden didn't seem so far-fetched anymore. □

Alcestis Oberg is a frequent writer on space and the co-author of Pioneering Space: Living on the Next Frontier. *Her article on the astronaut class of 1978 appeared in our October 1988 issue.*



I was wrong, Cliff, you DO have to be a rocket scientist to figure this out.



THE CHINA SYNDROME

China's entry into the commercial space arena is making Western launch companies plenty nervous.

By Thomas O'Toole

It's surrounded by soaring green mountains, reached only by twelve-hour trains or twice-a-week airplanes from the provincial capital of Chengdu. But the tiny town of Xichang, in a corner of China's remote Sichuan Province 175 miles east of Burma, is about to make news all over the world.

Never mind that the women of Xichang still do the family laundry in mountain streams, that their children still play barefoot outside houses baked in mud, or that water buffalo still pull wooden plows through Xichang's timeless rice paddies. Xichang is about to be launched into the high-tech and competitive world of the late 20th Century.

"Launched" is the operative verb in this case. Xichang will soon become the Cape Canaveral of the People's Republic of China, as soon as China and the United States hammer out the final details of their historic agreement allowing Chinese rockets to carry commercial satellites made in the USA into orbit.

Chinese rockets departing a *Chinese* launch base with *American* satellites. All for profit. It may mystify people who haven't kept up with the behind-the-scenes negotiations over the last few years, but the agreement is very real. After months of talks between the People's Republic and the administration of former President Ronald Reagan, it even earned Reagan's personal stamp of approval last year.

It all began when the Chinese realized their first rocketport, located in the Gobi Desert at Jiuquan, was too far north; they were wasting rocket fuel getting payloads into orbit without help from Earth's faster spin nearer to the equator. The government decided to open a second spaceport at Xichang, which lies at 28 degrees North—about as close to the equator as China gets (Cape Canaveral is 29 degrees North).

China's Long March launch vehicle also was building an enviable record: just one failure in 16 flights, with four straight successful launches out of the new Xichang site, starting early in 1986. In the meantime, the disastrous and expensive explosion of the space shuttle Challenger forced the shuttle out of the business of carrying commercial communications and navigation satellites into Earth orbit.

CHINA GREAT WALL INDUSTRY CORPORATION

China's Long March offers low fares, but some restrictions apply.

Enter the People's Republic of China, newly capitalistic, newly successful in the launch trade and eager to earn hard Western currency. China began talks very quickly with two neighboring owners of communications satellites, who just happened to be shopping for launch services. The Asiasat consortium, based in Hong Kong and financed in Great Britain, signed up for a single launch. An Australian group calling itself Aussat booked another pair of satellites.

Both organizations received cut-rate price offers from the Chinese. AsiaSat was given a price of $30 million for its single launch, and Aussat was charged the same amount for two launches. Even at the higher price, it was at least $60 million less than the U.S. "Big Three" companies (General Dynamics, Martin Marietta and McDonnell Douglas) were asking for a slot on one of their newly commercialized launchers, and about $30 million less than Europe's Arianespace was quoting.

Australia gave a simple explanation for going with the Chinese. "We're a

country with a huge external debt in terms of our balance of payments...and about a two-to-one trade deficit with the United States," the Australian Embassy's John McCarthy said in a public forum in Washington not long ago. "We stand to save up to $80 million U.S. dollars through this agreement with China, which makes this deal extremely important in terms of the Australian national interest." The people at AsiaSat gave a similar explanation when they agreed to the Chinese launch terms. "It's an offer," one AsiaSat representative said, "that's very hard to refuse."

Hard to refuse or not, the two agreements raised red flags across America. The three satellites in question were either built or scheduled to be built in the United States, which meant that American high technology could be compromised by a Chinese launch. The AsiaSat satellite is the old Westar-6, which originally belonged to Western Union. It was stranded in space following a malfunction after launch from the space shuttle's cargo bay in 1984, then was rescued and returned to Earth later that year by another shuttle crew. Western Union spruced up the salvaged spacecraft and sold it to AsiaSat.

"The recovered Westar-6 will be shared by a number of Asian countries, including China, Pakistan, Thailand and Korea," said Steven Levy, a Washington attorney who represents AsiaSat in the United States. "We looked at Westar-6 as an expedient to accomplish a communications business purpose, and we looked at the Long March in the same way."

But U.S. rocket companies saw China's discount pricing as an all-out assault on international fair trade, subsidized by the Chinese government and a labor force whose workers earn an average of $75 a month. China claimed its low launch price was no more than an "introductory, promotional" price to win its first customers. Still, American companies worried that the introductory prices would become permanent.

"If we were to turn these licenses down," said the State Department's Eugene McAllister, "I don't think anybody would think that the Chinese still aren't going to try and enter this market."

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When astronauts Joe Allen and Dale Gardner made this offer in 1984, few would have guessed that one of the satellites they retrieved would be re-launched on a Chinese booster.

"These are very significant price differences," said Dennis Dunbar, vice president and managing director of General Dynamics' commercial launch services division. If China were allowed to offer the same low rate to all its customers, he argued, "market disruption is sure to follow. The Western launch industry prices a launch on the basis of pounds into orbit. I would hope the Chinese would follow that pattern of pricing."

China's bargain-basement rates weren't the only concern of U.S. rocket manufacturers. China was claiming it could launch ten Long March vehicles a year; If all of these were paying flights, China would soon have half the world's commercial launch market. That's unacceptable to the U.S. industry, which sees China as a johnny-come-lately to a business already crowded with competition. "With the number of players in this business, four Chinese launches a year is probably too much and would be very disruptive," said Dunbar.

If it had chosen to, the United States could have vetoed China's entry into the world launch market. Because the satellites China plans to launch were all made in America, they are covered by American laws of technology transfer. Not only did the Pentagon and State Department have a say in licensing the export of the three satellites to China, so did the Transportation and Commerce Departments. At first there was a tug of war. The State Department and Commerce both wanted to grant the licenses. The Pentagon sat in the middle, demanding strict constraints on Chinese handling of the satellites. The Department of Transportation, which supports the fledgling U.S. commercial launch industry, was against it, arguing that the licenses would give

Have Rocket, Will Ride

Until the shuttle Discovery lifted off late last year, the 1988 record of space launches was written mostly on foreign ledgers. Hans Hoffman, a lanky, 53-year-old German aeronautical engineer, will do what he can to see that trend continue.

Hoffman heads Intospace GmbH, a European consortium of aerospace, chemical and conglomerate companies dedicated to spurring research, development and commercial production of products in space. Last August, after only an eight-month launch campaign, the group orbited a box containing 104 protein crystal samples aboard a Long March 2 rocket, a smaller and less capable version of the vehicle China is selling as a commercial satellite launcher.

Intospace offers several other opportunities for researchers who want to see what effect the low gravity of space has on certain materials. Hoffman believes all the average researcher cares about is results—not the nationality of the vehicle or other means used to obtain those results.

For the Long March flight, he and other Intospace officials picked up samples in the labs of participating researchers, integrated them into their "Cosima" experiment facility, transported them to China, flew them on the rocket, then returned the samples to the labs. Usually a great fan of the U.S. space program, Hoffman has criticized American reluctance to give foreigners equal access to flight opportunities.

"Compare that now with the Russians or with the Chinese. They have no restrictions. We have money, they want business. They don't ask if your passport is American or German; they really don't care. The attitude in how you treat the users is the main thing, and in this I can say that the Chinese have treated us like kings."

Despite the fact that some Cosima crystals were damaged on reentry, Intospace will fly another experiment with the Chinese this August.

—Melinda Gipson

China entry and an unfair edge in one of the few international high-tech markets where the United States still had a major share.

Nevertheless, an outgoing President Reagan said yes to the export licenses. Strict controls were agreed to during shipment, and even stricter controls are to be imposed when the satellites reach China, are moved to Xichang and are mounted on top of the Long March launch vehicles.

American diplomats and the U.S. launch industry won even greater concessions from the Chinese. China agreed to launch no more than nine international communications satellites through 1994—an average of 1.5 a year—and to keep launch prices on a par with the world market. The Chinese also agreed to require its launch marketing organization, the Great Wall Industry Corp., "to offer services, including insurance and reflight guarantees...on a par with those offered" by the rest of the worldwide launch industry.

The United States has approved the three export licenses, pending final signing of the trade agreement to cover the Chinese launch services. There was a good deal of diplomatic realism involved in the decision. "If we were to turn these licenses down," said the State Department's Eugene McAllister before the agreement was reached in late December, "I don't think anybody would think that the Chinese weren't going to try and enter this market" on their own.

Chinese rockets departing a Chinese launch base with American satellites. All for profit. It may mystify people who haven't kept up with the negotiations, but the agreement is very real.

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That was the bottom line. China has the Long March launch vehicle, a success rate that so far is the equal of what the Americans and Europeans have accomplished, and a willingness to accommodate customers. The Chinese have signed on to launch a Swedish satellite in the next year or so, and are expected to bid on the launch of a new Intelsat satellite and a broadcast satellite soon to be built for a group of American television evangelists.

The newcomers don't have everything going their way. The Long March still lacks the navigational accuracy of Europe's Ariane or America's Atlas, Titan or Delta launch vehicles; Long March users have to store extra maneuvering fuel on their satellites, at a cost of about $10 million and nine months of orbital lifetime. And the Chinese face another competitor in the years ahead. Japan already has announced it will enter the commercial launch business in 1992, and Brazil is making noises about following Japan before the turn of the century.

But with an agreement to launch American-built satellites already in hand, and the launch of AsiaSat on their calendar for next year, the Chinese now consider space a matter of serious business. □

Thomas O'Toole is a Washington freelance writer and national editor of AmericaWeek electronic newsmagazine.

A FIGHT FOR FREEDOM

NASA's "next logical step" faces a giant hurdle this year, not in space, but on Capitol Hill.

hen space station boss James Odom sees the Capitol building looming outside his window at NASA headquarters, he sees a hard sell. With lawmakers promising to get serious about the federal deficit, he must somehow snatch $2.1 billion—more than twice the money his program received last year—from a kitty that won't fatten.

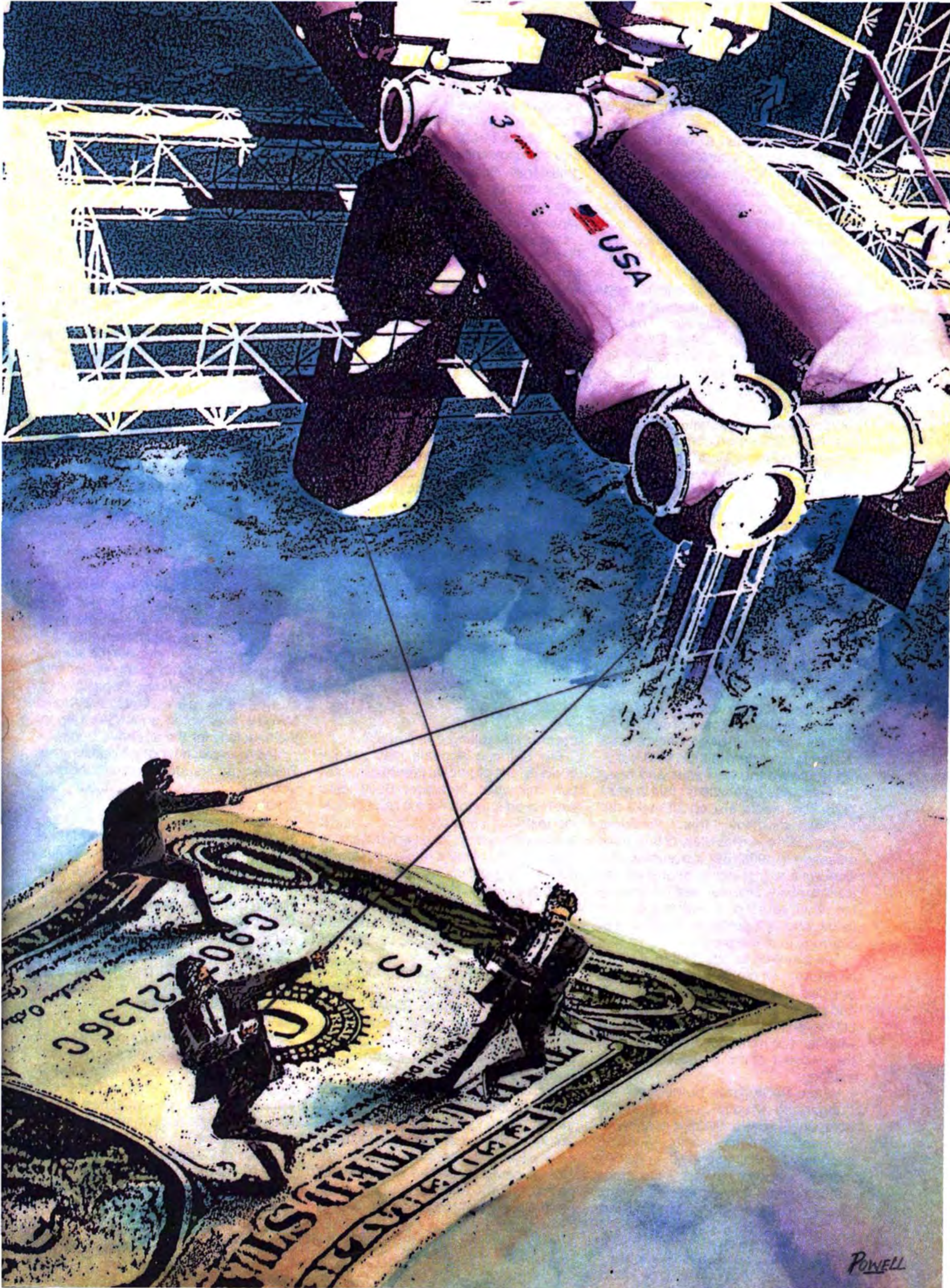
What Odom is selling is a home away from home for the space shuttle. But his color glossies, which will wind up on the desk of every space-voting member in Congress, right now are only drawings of tubes with Tinkertoy arms; metal for the real space station Freedom won't be bent for years. You want impact? Smoke and flame, a photographic bang for the buck? The shuttle folks are down the hall.

Odom knows that this year, his first as NASA's Associate Administrator for Space Station, will be pivotal. "We've got to decide once and for all whether we want a space station," he says in a friendly Alabama drawl aged over 29 years at Huntsville's Marshall Space Flight Center. "I'm not just worried that we'll drop the ball. I'm worried we'll put it down and walk away."

The fear isn't so much that Congress will abandon its investment—not after four years and $1.5 billion already spent. Rather, the budget-conscious legislators could pinch pennies to the point that the station's schedule gets stretched and costs become astronomical. Already the $28 billion estimate is three times the starting figure.

When NASA was developing the

BY PAUL HOVERSTEN


USA
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shuttle in the 1970s, it hoped the vehicle could eventually go *to* an outpost in space. But cost overruns in the shuttle program nixed that idea right away. Station planners had to wait until the shuttle became operational in the 1980s before they could hope to latch on to the big bucks.

Now that money is finally going toward the station project, promoters tout it as everything from a science laboratory to a steppingstone for Moon bases or human trips to Mars. Thousands of contracted scientists and engineers are toiling to make the dream NASA calls "The Next Logical Step" a reality by the late 1990s.

The stakes are high. The station is "absolutely vital" to further ventures in space, say officials in NASA's Office of Exploration, set up in 1987 on the advice of former astronaut Sally Ride. The office's first report concludes that a human mission to Mars, for example, can be attempted only after astronauts get used to long stays in space—presumably onboard a station.

International partners Japan, Canada and the 13-nation European Space Agency are planning their own technology to put onboard, having signed an agreement last September, on the day Discovery returned America to space. Japan and ESA will bring lab modules, and Canada will provide a robot arm similar to the shuttle's. Each is moving ahead on a piloted space program and, experts believe, all intend someday to occupy a station, whether America is there or not.

Plans call for NASA to decide on a design for Freedom in 1991, start building hardware the next year, and send the first piece up on the shuttle in early 1995. That would just about make the 10-year deadline that President Reagan laid out in his State of the Union message in 1984. But it assumes that Congress will approve nearly all the station money this year, won't chip away too much at billion-dollar requests to follow, and isn't pestered by more cost overruns from the shuttle.

The problem for the station, and for NASA as a whole, lies in how agency budgets get dished out from the federal pie. It has little to do with whether a lawmaker feels good about space or whether program managers can stuff the prettiest photo in the Capitol Hill mailbag.

When NASA gets burned on the budget, it's usually because of the company it keeps. Since it is an independent agency, with funding stamped "discretionary," NASA's money is appropriated by the same subcommittee that oversees a host of diverse social programs like housing, veterans affairs and the environment. The perception, right or not, that social interests went hat-in-hand during the Reagan years while high-tech was well fed caused trouble in Congressional districts back home. No more, say congressional staffers. There's only so much money to go around, and, as everyone knows, there are no constituents in space.

Last year, NASA Administrator James Fletcher twisted enough arms in Congress with his "make or break" speeches to wring a 19 percent funding increase—a total of $10.7 billion—for the space agency. It took tough bargaining, and shrewd maneuvers, to secure $900 million of the station's $967 million request. Late in the budget debate, NASA and Reagan christened the station "Freedom," a master stroke that left pundits wondering how anyone could vote against *that*. (NASA's ears had perked up early on, when some congressmen grumbled that the generic term made it sound like good money was going toward "an orbiting gas pump.")

There's only so much money to go around, and, as everyone knows, there are no constituents in space.

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But patriotic appeals may not be enough for a big-ticket item like the station this year. President Bush, who expressed support for the project during last fall's campaign, is up against lawmakers ready to divert dollars to neglected programs while sticking to the budget-balancing provisions of Gramm-Rudman. NASA's scouting report on the 101st Congress turns up several key new players it will be watching closely in the budget debate this spring.

One is Rep. Bob Traxler, a Michigan Democrat, who takes over from retired Rep. Edward Boland (D-Mass.) as head of NASA's budget subcommittee in the House. Traxler predicts the budgets will be painful for agencies under his care.

"When I took this job," he says, "I told Eddie [Boland] that with all the programs wanting more money, I'd be going to the cash register—and it's empty. He said 'That's why I'm leaving.' This is going to be the most difficult year that the Congress and the president have ever faced. The fun is over. There's no more fat to cut. We're down to amputating limbs."

Traxler rattles off past casualties in the independent agencies budget: crumbling veterans hospitals, overdue housing contracts, polluted air and water. Toss in money to start the newly approved superconducting supercollider for nuclear physics research, and "it's terrible choices you have to make. NASA deserves our attention. It's a valuable agency that plays an important role in high-tech areas and creates a sense of national pride. But if you cut the veterans to fund the space station, they're just going to show up somewhere else, in a different area of the budget."

Traxler guesses his subcommittee will need an extra $34.5 billion just to fund all the agencies adequately, with no big program increases. He has no idea where the money will come from.

Maryland Democrat Barbara Mikulski faces the same problem chairing the Senate budget panel that oversees the space program. Mikulski vigorously supports housing and the environment, but has reason to back the space station as well. Her state boasts the Goddard Space Flight Center in Greenbelt, one of four prime work sites assigned to the Freedom project.

Staffers point out that Mikulski, who replaces retiring Wisconsin senator William Proxmire, voted with the station last year when NASA backers yanked funds from the Defense Department's budget and gave it to Freedom. Mikulski later voted on NASA's side in the final tally for the agency's budget.

NASA's read on both Mikulski and Traxler as subcommittee heads: Untested. Lack the clout of predecessors.

Another new player is Sen. Al Gore, Jr., the former presidential candidate and Tennessee Democrat who chairs the science subcommittee that evaluates the initial space budget request. His predecessor, Sen. Don Riegle (D-Mich.), was a strong space backer who left to head the Senate Banking Committee. Gore, though, is no stranger to space. He was the only presidential candidate to push for a U.S.-Soviet human mission to Mars.

Gore is looking for help in pushing through the station's funding request this year. "It'll be difficult. I hope President Bush will support the space station and the majority in Congress will as well. It's an essential part of any NASA plan to develop longer-term missions in space."

Those in Congress looking for reasons to vote against the station have ammunition in a General Accounting Office transition report that went out to

members last fall. The GAO singled out the station as an example of NASA's failure to "report the full picture" of money needed for its activities. In 1987, NASA told Congress the space station would cost $14 billion—but neglected to mention that an extra $14 billion would have to be ponied up to launch and assemble it in orbit. "Omissions of this type are not unusual," the report said, noting that NASA tends to keep related costs separate from direct costs.

In early January, the National Academy of Sciences dealt the station another blow in a white paper submitted to President - elect Bush. Arguing that Freedom should be delayed until its purpose is made clear, the report said that "a permanently manned space station is essential to establish the feasibility of human exploration. But its final configuration, pace of deployment and funding level should not be established without prior decisions on American goals in space."

In deciding how to pay for major science initiatives like the station, Congress should consider a "cross-agency perspective," says a special committee of the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine. The idea is that agencies likely to benefit from the technology should help bear the cost. And funding for two years at a time, rather than annually, should be adopted, the panel says.

Managers like Clarke Covington, who runs the space station program at NASA's Johnson Space Center in Houston, are hit hardest when the bucks stop. Budget cuts mean overhauling schedules, revising contracts and setting new priorities.

"You can be nickeled and dimed to death," says Covington. "Every time we're fooled with changes in the budget, not only do things have to stretch out or the content has to come down, but everything gets more inefficient. If somebody would tell you, 'I'm going to fund your program for 10 years, this is what you're going to get every year, and this is your total,' no matter what it was, we could run a whole lot more efficiently. That'd be a dream to run a program like that."

Meanwhile, his prime contractor for station work, McDonnell Douglas Astronautics Co., is running dramatic TV ads to convince the public, and thereby Congress, of the need to get Freedom finished on schedule. A viewer sees a station passing, hears static-garbled voices, thinks they might be American. Wait! That's Russian! And there's the Soviet star on the bulkhead. An announcer comes on: "Shouldn't we be up there, too?"

One wild card in the debate over Freedom is a plan—still alive, but temporarily on hold—to have NASA help bankroll a much smaller commercial, unpiloted space station. As outlined in Reagan's national space policy, the government would lease 70 percent of a private facility for five years, starting in 1993. NASA's cost as an "anchor tenant" is estimated at between $400 million and $700 million. The most serious contender for the contract is Houston-based Space Industries, Inc., headed by spacecraft design pioneer Max Faget and former shuttle astronaut Joe Allen.

Congress last year ordered more studies on the demand for such a facility before agreeing to the proposal. Two independent panels, from the National Research Council and the National Academy of Public Administration, are expected to report their findings in mid-April.

With so many unknowns, and so many hungry agencies, NASA can't afford to sleep easy. The days of blank checks for the space program are but a memory for those in NASA's congressional relations office. "There's no question we have to get more sophisticated in our efforts, because you have a lot more agencies fighting harder for less money," says Lynn Heninger, the office's deputy liaison. "With the station, it's double the money and the federal budget is the same." He suspects top NASA brass will be spending more than half their time this year in Congress, charting the station to safety.

Astronauts also may find themselves on the case, flown in to warm up legislators who otherwise might not want to hear about space. There's no shortage of heroes in NASA, and the entree that the Right Stuff provides on Capitol Hill is irresistible to strategists. Says Heninger: "Astronauts have a role, but once you get those doors open, you've got to get other people in there to explain the details. You've got to have that follow-up."

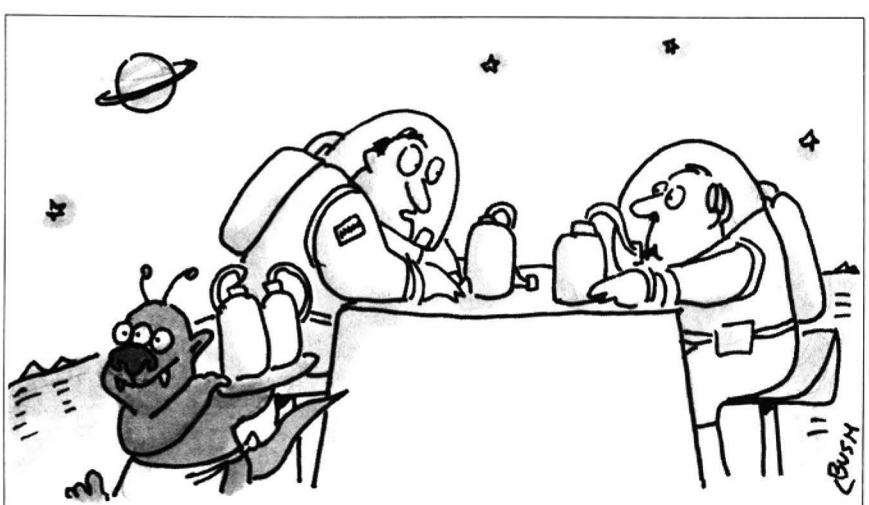
Shuttle pilot Jon McBride, NASA's point man with Congress, has worn out the shoe leather in his visits plugging the station as seed corn for future technology, hope in a competitive world. He remains cautiously optimistic. "We've got a lot invested already. I hate to think Congress would turn it off at this stage of the game. You've got to dedicate something to the future of this country."

A strapping ex-fighter pilot from West Virginia, McBride has a quick smile and firm handshake, good qualities to guide errant congressmen to the light. He knows firsthand the problems of selling an intangible like the station. His walls at NASA headquarters are covered with photos of smoke and flame, the shuttles he took up and back.

"You can go down to the Cape and see a shuttle launch, but you don't go down and see a space station launch. It's hard for the American public and Congress to picture a space station. It's an enigma."

McBride hopes to make converts before he returns to Houston and begins training to command the 35th shuttle flight, scheduled to launch in March 1990. "We're going to need logic to prevail, but you know how difficult it is for logic to prevail around here." □

Paul Hoversten is a national reporter for USA Today, *specializing in space issues.*



The portions are large and the food is good, but I'm not too wild about the atmosphere.

REVIEWS

Countdown: An Autobiography
by Frank Borman
with Robert J. Serling
Silver Arrow Books
448 pages. $19.95

By Les Dorr, Jr.

During his astronaut days, Frank Borman seemed to match the description his Apollo 8 crewmate Jim Lovell gave of the Moon: "Essentially gray. No color." In his later incarnation as TV pitchman for Eastern Airlines, he looked exactly like what he was—a corporate president walking his way rather stiffly through a scripted commercial.

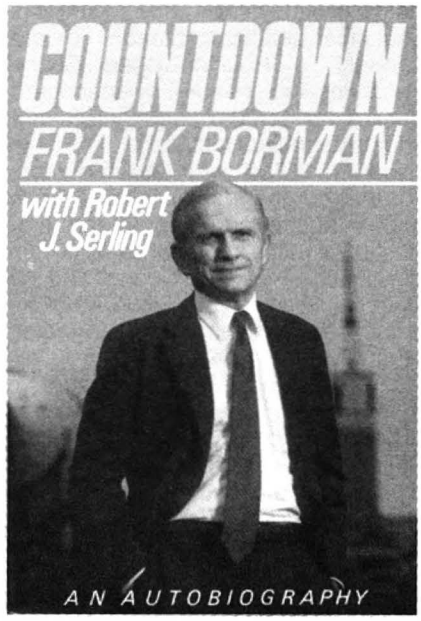
If Borman writes any more books like *Countdown*, he's going to spoil that bland, straight-arrow image.

As astronaut autobiography, *Countdown* easily ranks up there with the "industry standard," Mike Collins' *Carrying the Fire*. It's a crisp, compelling, intensely personal recollection of Borman's career, from his formative years as a West Point cadet to his futile struggle as head of Eastern Airlines to save the company from being sold.

Borman made just two space flights, but both were pioneering efforts. In December 1965, he and Jim Lovell stayed aloft for fourteen grueling days aboard Gemini 7, a spacecraft that had a livable area roughly equivalent to the front seat of a Volkswagen Beetle. Three years later, Borman commanded Apollo 8, the epic voyage that took humans around the Moon for the first time.

Borman does a masterful job of conveying the sights, sounds and smells of living and working in space. He describes his first Gemini sunrise as "a tiny wedge that kept expanding, until we had the illusion that we were looking into a huge cave with red mouth, yellow roof and blue outer rim. It was a light blue at first, then the cave seemed to explode in slow motion into a kaleidoscope of colors."

When Borman turns his attention to personalities rather than places, his narrative takes on a Mike Hammeresque pizazz. As the Apollo 8 crew



waits for the "go" to fire their third-stage engine and head out to the Moon, Borman visualizes Mission Control's Chris Kraft "chomping on one of those foul cigars, digesting the telemetry data and our own reports in that computer-calm mind of his" while Kraft "put Risk and Mission on his personal set of scales."

Borman likely had a large assist from co-author Robert J. Serling, a best-selling novelist; perhaps that's why *Countdown* seems so polished compared to most other astro- biographies. But the book has too much of an "I was there" flavor to be simply Serling's words over Borman's signature.

If your main interest is space exploration, you may be tempted to put *Countdown* aside after the first 270 pages, when Borman wings off to his new career at Eastern. But don't—you'll miss a crackling, intense, down-and-dirty corporate boardroom drama.

Eastern was a fractured airline when Borman joined the company as a vice president in 1970. Its New York and Miami offices were engaged in an insidious family feud, and the corporation's monetary situation was in a nose dive. When Borman ascended to the airline's presidency five years later, he stopped the internecine war, made Eastern's reputation for service the envy of the industry and managed to make the company at least financially respectable.

But to hear Borman tell it, he was shackled with his own personal nemesis. Charlie Bryan, head of the machinists' union in Miami, resented the ex-astronaut's celebrity status; "Frank Borman's had his Apollo 8," Bryan told Borman's wife, Susan. "I'm gonna have mine."

For the remainder of Borman's tenure at Eastern, Bryan and the machinists' union fought the company president's efforts to economize. In Borman's view, it was Bryan's intransigence that led to Eastern's flirtation with bankruptcy and the airline's ultimate sale. In the last 30 pages of *Countdown*, Borman turns what could have been a deathly dull account of a management vs. labor confrontation into a real potboiler. More than that, Borman makes you *feel* his predicament—and his heartbreak for the airline he loved—as he's caught up in a corporate Catch-22.

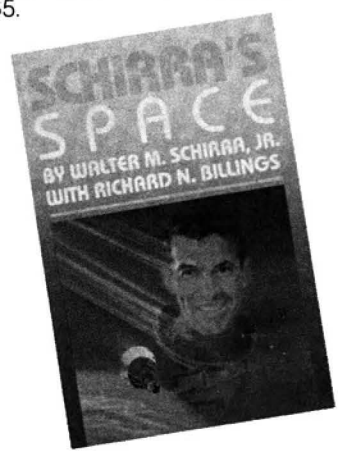
Frank Borman achieved fame with his high-profile accomplishments in space and aviation, but he came across as a one-dimensional human being. *Countdown: An Autobiography* will put that perception to rest. □

Schirra's Space
by Walter M. Schirra
with Richard N. Billings
Quinlan Press
230 pages. $16.95

Wally Schirra was the only astronaut to actually fly missions in America's first three piloted space programs: Mercury, Gemini and Apollo. In *Schirra's Space*, the irrepressible King of Gotchas writes a fairly straightforward account of his adventures, but manages to throw in a few zingers at NASA's current bureaucracy as well.

Schirra was known for his sense of humor as well as his competence. He had a self-confessed penchant for

practical jokes—the famous "gotchas" that are sprinkled liberally throughout this autobiography. Perhaps that's why I was so disappointed in *Schirra's Space*: it's flat. I expected a livelier, more colorful narrative from the man who once left a five-gallon jar of iodine-tinted water as a urine specimen, and who serenaded Mission Control with "Jingle Bells" played on the harmonica during his Gemini 6 flight in December 1965.



Schirra spins some priceless yarns, however, like the time he and Deke Slayton were fishing less than a hundred yards away from one of Cape Canaveral's launch pads when a Thor-Delta rocket began to lift off. Had there been an explosion, says Schirra, "it would have been a bad day for Mercury, with the chief astronaut [Slayton] and the pilot of MA-8 incinerated like the legendary rattlesnakes."

For Schirra, his Apollo 7 flight, the shakedown cruise of the spaceship that would later take men to the Moon, was an anticlimax—little more than "boring holes in space." He scratched off each day of the mission on a small metal calendar "as if I was a prisoner or a man marooned on an island." And Schirra laments the handling qualities of the Apollo craft with the most telling epithet an ex-fighter jock can muster: He calls it a "big bomber."

That same grumpy elitism pervades *Schirra's Space*. His comment that "people who don't fly the spacecraft" shouldn't be called astronauts will draw snarls (and a few amused chuckles) from NASA's corps of shuttle mission specialists. Schirra also believes that Jeana Yeager, co-pilot of the Voyager round-the-world aircraft, should be only an *honorary* member of the Society of Experimental Test Pilots—she doesn't qualify according to his technical standards.

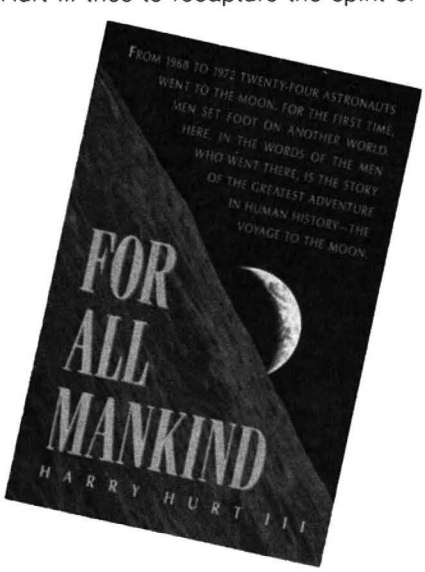
Ultimately, there's nothing really right *or* wrong with *Schirra's Space*. It's just there, kind of like literary Chinese food. An hour after you read it, you'll be hungry for something else. □

For All Mankind
by Harry Hurt III
Atlantic Monthly Press
352 pages. $22.95

A lot of people say space today is *boring*. Watch the Russians go round and round, watch the shuttle go up and down. Yawn.

No one described NASA's space program as "boring" twenty years ago. It was the Era of Apollo: daring young Americans hurtling away from Mother Earth, reaching out to meet the mandate of a martyred president and, in the process, fulfilling the dream of centuries—to set foot on the Moon.

Newsweek correspondent Harry Hurt III tries to recapture the spirit of Apollo in *For All Mankind*, an overview of the U.S. lunar landing program built largely on quotes from the Apollo astronauts. On the strength of its source material alone, this book should have been a winner; Hurt had access to more than 90 hours of interviews with the astronauts taped by Al Reinert, who is producing a film with the same title as Hurt's book.



As long as Hurt lets the men who were actually there do the talking, *For All Mankind* is a gem. Consider Charlie Duke's recollection of the bone-rattling liftoff of Apollo 16: "...I was just sitting there shaking like crazy. I really wasn't mentally prepared for that. My first reaction was, 'Gosh, this thing can't fly. It's going to shake to pieces.'"

Unfortunately, the narrative that Hurt weaves around the astronauts' words is riddled with fractured facts and half-baked conclusions. Most readers will probably pass over Hurt's mention of Apollo's "custom-molded" crew couches (they were abandoned after Mercury) or his placement of Apollo 12's lunar landing in December 1969—a month after the mission took place.

But anyone with even a casual knowledge of Apollo will pick up on Hurt's repeated reference to the "dark side" of the Moon (yes, he *really* doesn't realize that it isn't always dark on the hidden side). Neil Armstrong will be surprised to learn that he "methodically climbed out through the roof" of the lunar module. (Watch that first small step, Neil!) And how does Hurt come up with the downright goofy deduction that if the Apollo 15 astronauts hadn't stopped a water leak in the command module, "all three would have drowned in space?"

Okay, anyone can make a mistake. But when factual errors show up literally on page after page, they destroy the author's credibility. Where did Hurt's researchers—he acknowledges five of them—find this stuff? Where were his editors? In short, does Hurt know what the hell he's talking about?

Leave *For All Mankind* to wind up on the "books for under $1.00" table. Save your pennies for the movie. □

SPACEFARERS

A Declaration for Mars

What is the common ground that unites Muppets creator Jim Henson, newscaster Walter Cronkite, actor James Earl Jones and author Norman Vincent Peale?

Hint: It's about 35 million miles away.

In recent months, all four celebrities have added their signatures to The Mars Declaration, a document advocating "the goal of human exploration of Mars" and urging "that initial steps toward its implementation be taken throughout the world."

The Martian manifesto is being circulated by The Planetary Society, a 120,000 member space advocacy group dedicated to planetary exploration. The Declaration was first publicly announced by the society in 1987, and has several aims—the most important of which is to establish Mars as a long-term goal for the space program.

"Mars is the most ambitious goal that anyone has discussed," explains Tim Lynch, the society's Mars Campaign Director, "and it is one that would require the infrastructure that would satisfy the advocates of many other manned activities in space."

Setting a challenging goal, the Declaration's proponents argue, will provide a coherent focus and sense of purpose to NASA. It also would keep space research and development activities on an appropriate schedule, and give an unambiguous purpose to NASA's space station *Freedom*.

The Planetary Society hopes to use the document to inspire and educate the public about the benefits of human Mars exploration. The Declaration starts with vivid descriptions of the planet, and goes on to enumerate the various scientific questions, including the existence of present or past life, that could be investigated by humans on the Martian surface.

Signing up with Sagan

▼ ▼ ▼

By Eric W. Tilenius

Although the Declaration doesn't specifically call for a joint U.S.-Soviet mission, long-time Mars booster and Planetary Society President Carl Sagan, who was instrumental in forging the document, praises Mars exploration as a "realistic and possibly unique opportunity for the United States and the Soviet Union to work together in the spotlight of world public opinion, and with other nations, on behalf of the human species."

The Declaration will eventually be presented to Congress and to President Bush to show widespread support for space missions in general, and Mars missions in particular. Polls already have shown strong support for human Mars exploration—an Associated Press-Media General poll last July showed 64 percent in favor of some program to land astronauts on the Red Planet, as compared to 55 percent in favor of the space station. But according to Congressman Robert J. Mrazek, a New York Democrat who favors human missions to Mars and who bills himself as "a strong supporter of the space program," Congress still needs some convincing.

"Not nearly enough of my colleagues, or the public at large, understand the tangible benefits associated with a vibrant national space program," wrote Mrazek last March. Although he calls space policy an area increasingly "seen as the key to our future on Earth," Mrazek says that he and his fellow Congressmen rarely receive letters on the subject, which sends a negative message to politicians.

Proponents of the Mars Declaration hope their document will show unequivocally that the citizens do care. Already it has gathered the support of a surprisingly diverse group of big names. Johnny Carson, Ted Turner, Jimmy Carter, Jeane Kirkpatrick and James Michener all have signed, and the "partial list of signatories" released by The Planetary Society reads like a "who's who" from all fields.

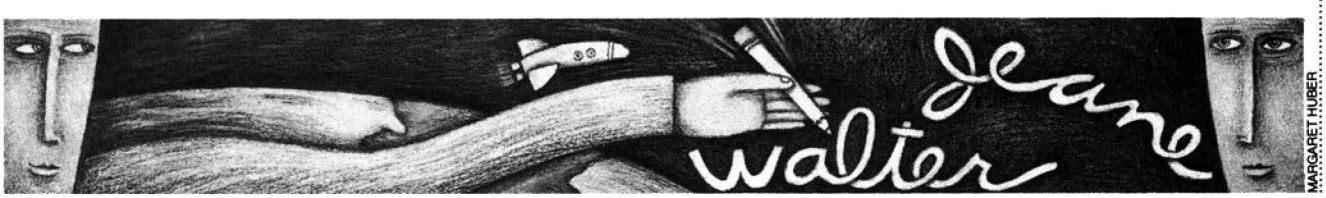
The list includes Nobel Laureates, sports figures, astronauts, armed forces generals, leaders of peace groups, poets, politicians and religious leaders.

So far, the society says it has collected tens of thousands of endorsements, and hundreds more are pouring in daily. According to Tim Lynch, most of the signatures are expected to be on hand by July 20, the twentieth anniversary of the first Moon landing.

While no national decision has been made on what the next major space program goal should be, the Planetary Society does not see the Mars goal as controversial. The perception that space exploration is unnecessary or unaffordable is the real hurdle that needs to be overcome, say Declaration supporters.

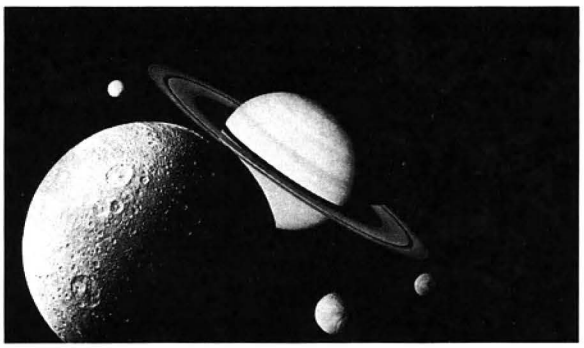
"That people from such diverse backgrounds, occupations and political philosophies are willing to let their name be publicly associated with this is proof that the document works," comments Lynch.

"A one-shot mission, or no mission at all, will not be the situation if there are organizations dedicated to the Mars goal and people committed to it—people who are willing to put themselves on the line for what they believe in." □



MARGARET HUBER

Does exploring other worlds make your heart beat faster?



Help launch a new era in planetary exploration... and enjoy the many benefits of membership in The Planetary Society.

This is an important time for space exploration enthusiasts like you. At no other time in history has the exploration of other worlds held more promise. Through your membership in The Planetary Society, *you* can help fulfill this promise...*you* can have an impact on the exploration of other worlds and the search for extraterrestrial intelligence.

In the last two decades, for the first time in history, we have studied our neighboring worlds close up and in detail—the enigmatic pyramids of Mars, the organic clouds of Titan, the 10,000 Saturnian rings. Right now, the U.S., the U.S.S.R., the European Space Agency and Japan are planning historic space missions. These epic ventures will be remembered by our descendants thousands of years from now when most other achievements of our time will be forgotten.

See the universe in a new light

The Planetary Society, as the world's largest, most influential space interest group, will have an impact on such programs. And you, as a Planetary Society member, will be a part of our efforts. As a member, you not only take a front-row seat in the ultimate adventure in space. Your membership will actually help move ahead international programs to explore the cosmos...will actually help finance the radio search for extraterrestrial intelligence.

Headed by some of the world's most distinguished scientists, The Planetary Society provides more than 100,000 members with knowledge and inspiration that sparks their imaginations and keeps them on the cutting edge of space exploration.

U.S. Planetary missions scuttled. New hopes for new missions.

Since 1978, the U.S. has not launched a single mission to the planets—after dozens of historic missions in the preceding two decades. Today, The Planetary Society is spearheading efforts to renew U.S. commitment to missions awaiting launch: *Galileo, Magellan, Ulysses* and *Mars Observer.* And we are disseminating information to the American people on the ambitious Soviet *Phobos* mission and on future Soviet Mars exploration. We are also leading the drive for a multinational piloted mission to Mars and new expeditions to other planets. We invite you to join us.

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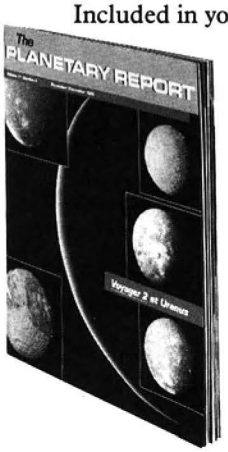

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Co-founders of The Planetary Society: Bruce Murray, Professor of Planetary Sciences, California Institute of Technology (seated left); Carl Sagan, Director, Laboratory for Planetary Studies, Cornell University (seated right); Louis Friedman, Executive Director (standing).

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AA09

VIC COX

Mr. van den Berg Goes to Space

Shuttle astronauts come in all shapes and sizes. And some are just regular folks like us.

By Vic Cox

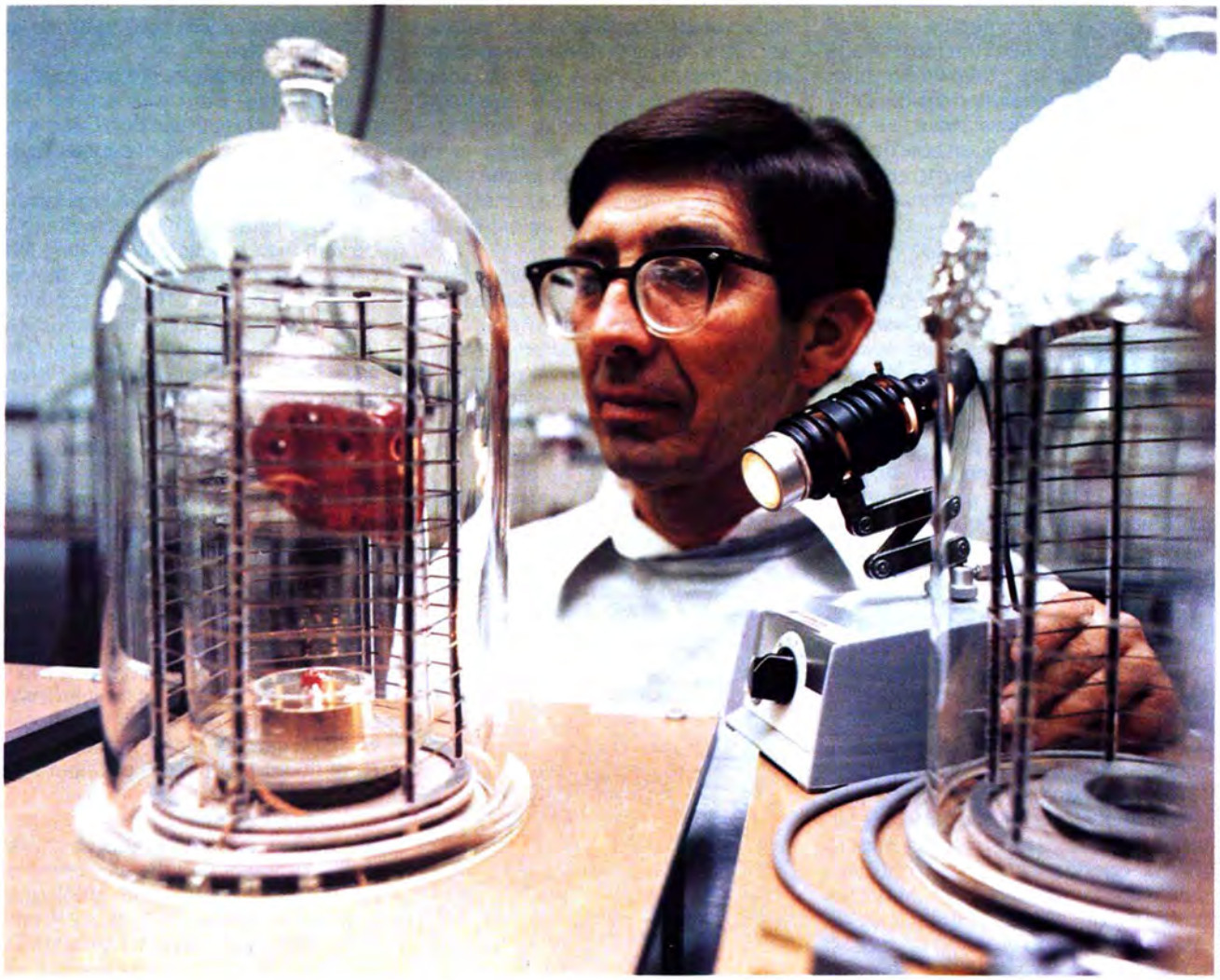
Ask scientist Lodewijk van den Berg about his experience aboard the space shuttle and he'll tell you, "It changes your perspective." Obvious, you might think. But those changes occasionally catch even him unawares.

When a group of Australian researchers visited van den Berg's laboratory in Santa Barbara, California, they asked if he'd ever been to their country. "I told them I'd never been there, but I've seen all of it, which puzzled them a bit," he laughs. "Sometimes it comes out in silly things like that."

Few people can bear personal witness to how different the environment of space really is. Most astronauts and cosmonauts come from military backgrounds, and many are former test pilots. But an increasing number are civilian "payload specialists," selected and trained to conduct experiments that are beyond the expertise of the professional NASA shuttle crews.

Payload specialists have another, unique distinction: They come closer to representing the average American than do the professional astronauts—or the two members of Congress—who have ridden aboard the shuttle.

Dutch-born Lodewijk van den Berg rocketed into low Earth orbit in spring of 1985 as a payload specialist for the Spacelab 3 mission. Recognized as a U.S. expert in making crystals grow, his assignment was to do just that in microgravity. Using a low- power, low-heat furnace, he hoped to produce a mercury iodide crystal that would have fewer structural flaws and better electrical properties than crystals grown on



EG&G ENERGY MEASUREMENTS

Lodewijk van den Berg in his EG&G lab. His main task aboard Spacelab 3 was to grow crystals better than any produced on Earth.

Earth using the same process and same material.

When Challenger reached orbit, van den Berg found he had much more pressing, and prosaic, matters to deal with. "The first thing they do in orbit is activate the bathroom," he says. Fluids rising inside the body do more than bloat the face; they also trigger rapid urine production. Van den Berg also felt queasy, a sensation familiar to most spacefarers during their initial adaptation to weightlessness.

One difficulty in dealing with space sickness is that there's no sure way yet to identify before a flight who will lose their cookies in space. During two years of preflight training, van den Berg underwent standard susceptibility testing, in which your senses are disoriented until your stomach rebels. There were practice free-falls in a KC-135 jet—40 a day, for periods of three consecutive days. "You were black-and-blue after a day of practice," says van den Berg, "but you learned to protect yourself."

In an experiment to control physiological changes associated with nausea, van den Berg was trained in biofeedback techniques. He learned to master his heart rate and body temperature while seated. "It sure beats running (for exercise)," he quips. He credits the method with helping him quell his initial queasiness in space. "Some people say biofeedback is hogwash, but for me it worked like a dream." Food helped, too. Van den Berg ate about two hours into the flight, and the queasy feeling left him, never to return.

Figuratively and literally, he had come a long way from the farm village in The Netherlands, where he was born in 1932. He demonstrated his curiosity early on: When he was about five, van den Berg decided to learn how carrots grew, so he pulled up a few to see how their roots were doing. Fortunately, his parents understood the scientific method and tolerated the loss of a few vegetables.

By the time he was in training to be a chemical engineer in Holland, van den Berg's interests were "more toward answering the 'whys' than the 'hows,'" he recalls. One of his advisors at the Technical University in Delft—the Dutch version of M.I.T.—recognized his research orientation and steered him to the University of Delaware in 1961, where he got a job as research assistant to a professor who was exploring x-ray analysis of crystalline materials.

Van den Berg stayed at Delaware for the next 14 years, earning his Ph.D. and working with the electrical properties of crystals and their application to semiconductors. When EG&G Energy Measurements, a defense contractor, advertised for a chief crystal-grower in 1974, he was quickly hired.

The crystal expert had his work cut out for him aboard Spacelab 3 more than a decade later. The flight plan called for completion of 15 materials science and physics experiments in seven days, which required almost full attention from van den Berg, who represented EG&G, and fellow payload specialist Taylor Wang of the Jet Propulsion Laboratory.

Van den Berg's primary task was to grow a mercuric iodide crystal in a glass ampule not quite seven inches high. Using carefully controlled heat and pressure, material inside the ampule was vaporized and deposited on a three-millimeter-high seed crystal at the bottom—a process called "vapor transport."

At first, van den Berg admits, he was doing all the sweating. "For the first 14 hours of the experiment, the crystal wasn't growing," he remembers. A video camera mounted on the furnace relayed pictures of the seed to an EG&G team working with NASA technicians at Johnson Space Center, so they also knew something was wrong. The ground "crew" worked with van den Berg for hours to arrive at the right mix of temperature, pressure and rate of vapor transport before the crystals finally started growing.

After another 90 hours, the ruby-red crystal had surpassed all projected growth rates, and the glass capsule was cooled and removed from the furnace. Van den Berg and his colleagues wanted to apply their hard-won knowledge toward growing another space gem. Just hours before the crew began to prepare Challenger for landing, a second ampule was inserted in the still-hot furnace. The two-in-one experiment was a success, with benefits that only became evident later, on the ground.

Unlike most of those grown on Earth, the whole crystal—not just parts of it—was of high quality. When its electrical properties were measured, says van den Berg, the results were eight to ten times better than the average ground crystal, and three times better than the best produced in Earth laboratories.

"That's impressive," he boasts.

Science dominated van den Berg's time in space, but he also had other, less glamorous chores. At one point he had to don surgical mask, gown and gloves to help two other astronauts clean up food and feces that had blown out of a prototype rat and monkey cage.

EG&G ENERGY MEASUREMENTS

Van den Berg's mercuric iodide crystal (at bottom) grows magically in zero-g.

When they were off-duty, the crew members would eat, take sponge baths or strap themselves into their sleeping bags. When they wanted relaxation there were music tapes and zero-g games to play. Drinking bubbles was one popular sport. Fruit drink is sucked out through a flexible plastic straw, then expelled so that its own surface tension makes it float like a colorful balloon in mid-air. The goal is to insert your straw into the bubble and suck it up from the inside. It's not as easy as it sounds. As soon as the straw touches the bubble, the liquid runs up the straw. You're also floating in mid-air, with no traction.

"It takes a whole lot of body control," says van den Berg with a grin. "Our commander (astronaut Bob Overmyer) was a champ at it and, of course, Taylor Wang is an *expert* on bubbles."

Van den Berg's warm feelings toward his crewmates may have something to do with their practice of donating leftover food to his insatiable hunger during the mission. "On the ground, I was a careful, moderate eater. Up there, I ate everything in sight," he says. "I hoarded others' leftovers. It was totally crazy." He also thinks he may have set a new NASA record. Usually, shuttle astronauts lose from four to six pounds. He gained two.

For van den Berg and many other astronauts, the primary use of free time was for Earth-watching. With the shuttle upside down and traveling almost horizontal to the blue-green globe, the best views were from the aft flight deck. Van den Berg says that the orbiter's eight windows—six in front and two in back—reminded him of a picture window. "It made me dizzy," he recalls, when he saw the planet below zipping by at about 17,500 miles per hour, "but then, it was fun."

From that perspective, says van den Berg, there is no separation between oceans, clouds and the sky. Likewise, national boundaries and ideological issues disappear. "A farm in Poland doesn't look any different than a farm in southern Spain," he observes.

Some distinctions, both natural and man-made, were very clear from space. The shuttle passed over the Great Lakes every second day, and the astronauts could see the ice packs breaking up, almost as if they were watching time-lapse photography. Van den Berg also noted a "big black strip stretching from Chicago to the East Coast, the result of acid rain damage." The dull gray spread of marine pollution followed long stretches of America's eastern seaboard and covered the Mediterranean, North and Baltic Seas. "Now, I wouldn't dare swim in any of those seas," says the transplanted European.

"Going into space is an emotional experience for many people," he continues. "I came back wanting people to protect and care for the planet better. Looking at it gave me a definite feeling that that was my world and that's where I belong."

When the scientist/astronaut returned from more than 2.5 million miles of space travel, he found that suddenly people wanted to hear his views. Schools and clubs invited him to appear. Van den Berg likes it that way,

though he admits that having an astronaut father was "no big deal" to his two children. To a local newspaper reporter he explained, "To people my age, rockets in space are new, a big thing. But my children, from the moment they began watching TV, have been seeing rockets. Lots of people do it, right?"

Just eight months after van den Berg's journey into orbit, Challenger blew up 73 seconds after liftoff. The news stunned van den Berg—he knew astronaut Judy Resnick personally—and he considered calling off a scheduled talk at an elementary school near his home in Santa Barbara. Instead, he met with the school superintendent and an officer from nearby Vandenberg Air Force Base and decided to carry on. The children were expecting him.

"It was really weird," he recalls. "The kids were less upset than the teachers." He gave his standard talk and got a few laughs with some humorous comments. Afterward, van den Berg overheard a second-grader being asked by a TV reporter for a reaction to the Challenger explosion.

"On the ground, I was a careful, moderate eater. Up there, I ate everything in sight."

▼ ▼ ▼

"That was bad," he recalls the child saying. "Last week, my big brother died in a car accident. That was really bad."

Perhaps, van den Berg suggests, adults could learn something about priorities from that child. Going into space aboard a complicated craft strapped to explosive fuel tanks will always be a hazardous undertaking. It should never be treated with complacency, and there will be always be a human cost for any new and risky enterprise.

As for Lodewijk van den Berg, his hat is in NASA's ring again. He's a candidate for a new Microgravity Lab mission tentatively set for launch in 1991. He hopes to repeat and expand his earlier successes growing space crystals. And why not? His track record is truly out of this world. □

Vic Cox is a Santa Barbara freelancer interested in the human side of space exploration.

Roads to Mars

continued from page 36

engines. Testing such a vehicle in space presents a major political hurdle, unless underground tunnels used for bomb tests could be adapted for test-firing the rockets on Earth.

Even more promising, perhaps, is "nuclear electric" propulsion, or NEP. Instead of heating up an exhaust fluid directly, a nuclear reactor would be used to produce electricity that would expel charged particles at high velocities out the back of a low-thrust engine. The principle has already been demonstrated on satellites in Earth orbit, and the Defense Department is now building a nuclear reactor for generating large amounts of electrical power in space.

An advanced NEP rocket could revolutionize the Mars journey. It would have ten times the fuel efficiency of chemical rockets, which makes it perfect for the heavier (and slower) cargo half of a split/sprint mission. Although an NEP vehicle would be great on gas mileage, it's weak on thrust, and takes a long time to build up speed. For that reason, it's usually ruled out in NASA case studies for carrying the crew—too slow for a sprint to Mars.

But Paul Keaton of Los Alamos thinks the conventional wisdom has it all wrong. He sees NEP-powered vehicles delivering humans to Mars in about four months, if they wait until *after* the Mars-bound ship has built up speed—in a long, slow spiral outward from Earth orbit—before boarding it (using a smaller orbital transfer vehicle) to head toward Mars.

Most experts think nuclear electric propulsion also could be ready early in the next century, if we begin work now. With NEP's low thrust and steady acceleration, the farther we go, the greater the advantage. According to Keaton, that means nuclear electric propulsion could open up the whole Solar System *beyond* Mars.

A 1987 National Research Council report on the future of space technology concluded that "a revolutionary approach to advanced propulsion concepts is essential if the United States is to regain its world leadership position in space." Bill Strobel, who traveled many of these same roads while conducting NASA-sponsored studies for General Dynamics in the 1960s, agrees that advanced propulsion is the way to go to Mars.

"If we go with chemical systems and aerobrakes," he says, "it's as if we're forcing ourself [to do a Mars mission] before we're ready."

Whatever path we take, and however soon we go, the first Mars voyage will almost surely be an international expedition. It's hard to imagine that American astronauts would go it alone after years of working closely with the Europeans, Japanese and Canadians onboard space station Freedom.

Cooperation with the Soviet Union is another possibility; with or without us, the Soviets have their own plans for Mars. On a recent visit to the Soviet "mission control" in Kaliningrad, one American observer was shown a planning chart, which had the first expedition (using the heavy Energia rocket and a nuclear propulsion stage) leaving for Mars sometime between 2006 and 2015.

Should we race? Not all sprint missions are created equal— the best "oppositions," or favorable alignments, happen every 15 years. In 2003, Mars and Earth will be about as near to each other as they get. If we don't go until 2011, when the planets are farther apart, the same mission might cost more than two and a half times as much. Waiting has a price, too.

In the meantime, John Soldner and his colleagues keep tweaking their trajectories at SAIC, looking at different departure times, trying to save a little fuel here or a few days of travel there. NASA continues to do its paper studies, while trying to keep its budgetary head down.

What we need right now, say managers in the Office of Exploration, is a steady, low-level commitment of money, including continued progress on a heavy-lift launch vehicle for reaching Earth orbit (an absolute necessity for *any* Mars mission) and more funding for the "Pathfinder" technology development program.

On that score, the Reagan Administration, always long on grand pronouncements about space and short on follow-through, set a dismal precedent. Pathfinder, which aims to develop such critical Mars technologies as aerobraking and the transfer of cryogenic fuels in orbit, received only $40 million of the $100 million requested for the program last year. This year's allotment is a paltry $47 million. We won't get to Mars, or anywhere else that way.

But if NASA's long-range strategists are right, then we may not need a Kennedy-like declaration of goals from the new President—at least not until the end of his term, when the space agency is ready to recommend a course of action. For now, they say, if you want to know how we're faring on the road to Mars, don't read George Bush's lips. Read the fine print in his budget. □

Being There

continued from page 40

faces of the buildings.

Possible Martian cities often are compared with Antarctic bases on Earth, but they might be even more comfortable. Settlers couldn't play pool in the recreation room; the low gravity would hinder their game unless the balls were made of lead, which is rather hard on the cues. But most forms of entertainment and diversion would be just as good on Mars as they are here. In the low gravity, sport lovers could drive a golf ball halfway to the polar cap, or knock a home run into the next crater.

We could grow virtually anything in a Martian garden, suitably enclosed and protected from the hostile environment. A 60-acre farm on Mars could support several thousand people, and new advances and research on high-density farming techniques could improve that figure substantially.

And there are even a few ideas—perhaps premature—for the open country lying out beyond the first permanent Mars base or even the first capital city. What will we do with the leftovers from the garden? Feed them to the animals. Artificial insemination practically eliminates the need for a Martian Noah's Ark to deliver animals to the "new" planet. We'll leave the billy goat back on Earth, where he won't have to deal with weak gravity or be laughed at; instead, we'll likely import sperm and ova to Mars and make our own test-tube animals.

Chickens make eggs, and are expected to do so even on Mars. Two rabbits can produce a litter every two months and be fed from a square yard of alfalfa—rabbit stew may be a staple of Martian cuisine. Goats can provide milk, are easier to feed than cattle, and don't take up as much room.

If you're going all the way, you might as well include the horses. That way, the roses (red roses, of course, for Mars) will have a steady supply of nutrients. If you can figure out how to put a space suit on one, you could head out for the Mariner Valley on vacation.

So there's our "new" Mars: settled and colonized sometime in the 21st century, using mostly native materials, with only a few imported items. Cities of glass bricks and concrete, furniture of plastics, the interiors of the buildings lit indirectly by natural light from solar collectors; Martian dirt everywhere for protection from cosmic rays.

"If we have some good luck with our work here at the University of Arizona labs," says John Lewis, "it will be a Mars that is as independent of resupply as possible. I hope that the technologies that we can start developing in the near future will be great positive incentives for mankind, real enabling factors in the exploration of the Solar System."

And what of the question of Martian life? Some scientists still hold out for the presence of life there, based on inconclusive results from the Viking landers in 1976. Isn't all that digging, stripping of permafrost and bull-dozing of the landscape for settlements going to stir up the environmentalists? What if we destroy a Martian life form, however insignificant?

"Finding life on Mars from Viking data," says Lewis, "is a performing art. Other than the Sun, I can't think of *any* place less likely to have organics...."

Perhaps, but Mars often speaks with a forked tongue, as some wag once remarked.

Robert M. Powers is the author of Planetary Encounters *and* Mars: Our Future on the Red Planet.

Phobos

continued from page 31

solar wind. Equipment onboard the spacecraft also determined the characteristics of interplanetary shock waves and the location of gamma ray outbursts.

Halfway into the mission, however, the normal course of events was disrupted. During a communications session scheduled for September 2, no signal was received from Fobos 1—the result of an operator's mistake in relaying commands to the spacecraft, which led to a loss of orientation and the spontaneous discharge of onboard power sources. Attempts to restore communications lasted for a month. There was hope that in the process of uncontrolled rotation, the probe's solar cell panels would turn at least for some time toward the Sun and recharge the buffer batteries. Yet all efforts proved futile, and Fobos 1 was irretrievably lost.

Now all attention is focused on Fobos 2, which was scheduled to reach the environs of Mars at the end of January.

Closing in on Phobos directly from the interplanetary trajectory is impossible—it would be easier to hit a bullet with a bullet than Phobos with Fobos. Modern science has little knowledge of the Martian satellite and its orbit. All of our information comes from Earth-based observations (during brief visibility periods), and from data relayed by the U.S. Mariner 9 and Viking 1 probes. That is why Fobos 2 must first become an artificial satellite of Mars and carry out preliminary observations from a circular equatorial orbit around the planet.

The transition into an "observation orbit" is accomplished by firing retrorockets at three specific points of the trajectory to transform the spacecraft's orbit gradually from a hyperbolic to an elliptical, then a circular one positioned some 220 miles above the moon's orbit. That orbit continues for about a month. During this time, onboard systems will verify the elements of the moon's orbit and will measure the probe's own movement in relation to Mars' natural satellite. Parallel with this, the spacecraft will relay TV pictures back to Earth for verification of the terrain features.

At orders from ground control, the probe will switch over to an orbit synchronous with Phobos. The next two months will be taken up by the retrieval and processing of information which will allow the spacecraft to approach within 22 miles of Phobos. After that, at orders from its own systems and instruments, Fobos 2 will begin closing in on the Martian satellite. Hovering about 160 feet above the surface, the spacecraft will sail over Phobos and conduct experiments for 25 minutes.

That drift, even at a low speed, will be very hard to accomplish, if only because Phobos is covered with craters and deep furrows. A hedge-hopping flight over them is possible only if the probe is "smart" enough. The onboard computer system must promptly evaluate the situation and make the right decisions. It must also maintain altitude control at all times.

The research program at that stage includes television surveying, radar scanning of the sub-surface structure of Phobos, and the evaporation of matter samples with laser and ion-beams to study chemical and physical properties of the soil. Two descent modules also will be dropped onto the surface of Phobos: an autonomous stationary monitor and a mobile probe. They will relay panoramic views of the tiny moon's surface, study the soil's mechanical, physical and chemical properties, and measure the magnetic field.

Upon completing these investigations at Phobos, the interplanetary spacecraft will switch over to other tasks. These include remote probing of the Martian surface and the planet's atmosphere.

In effect, this is the beginning of a new stage in Martian studies. The goal is to locate areas with maximum humidity on Mars where it would be most expedient to look for signs of life, and to determine where new research spacecraft should be sent in the future.

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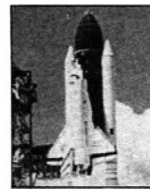

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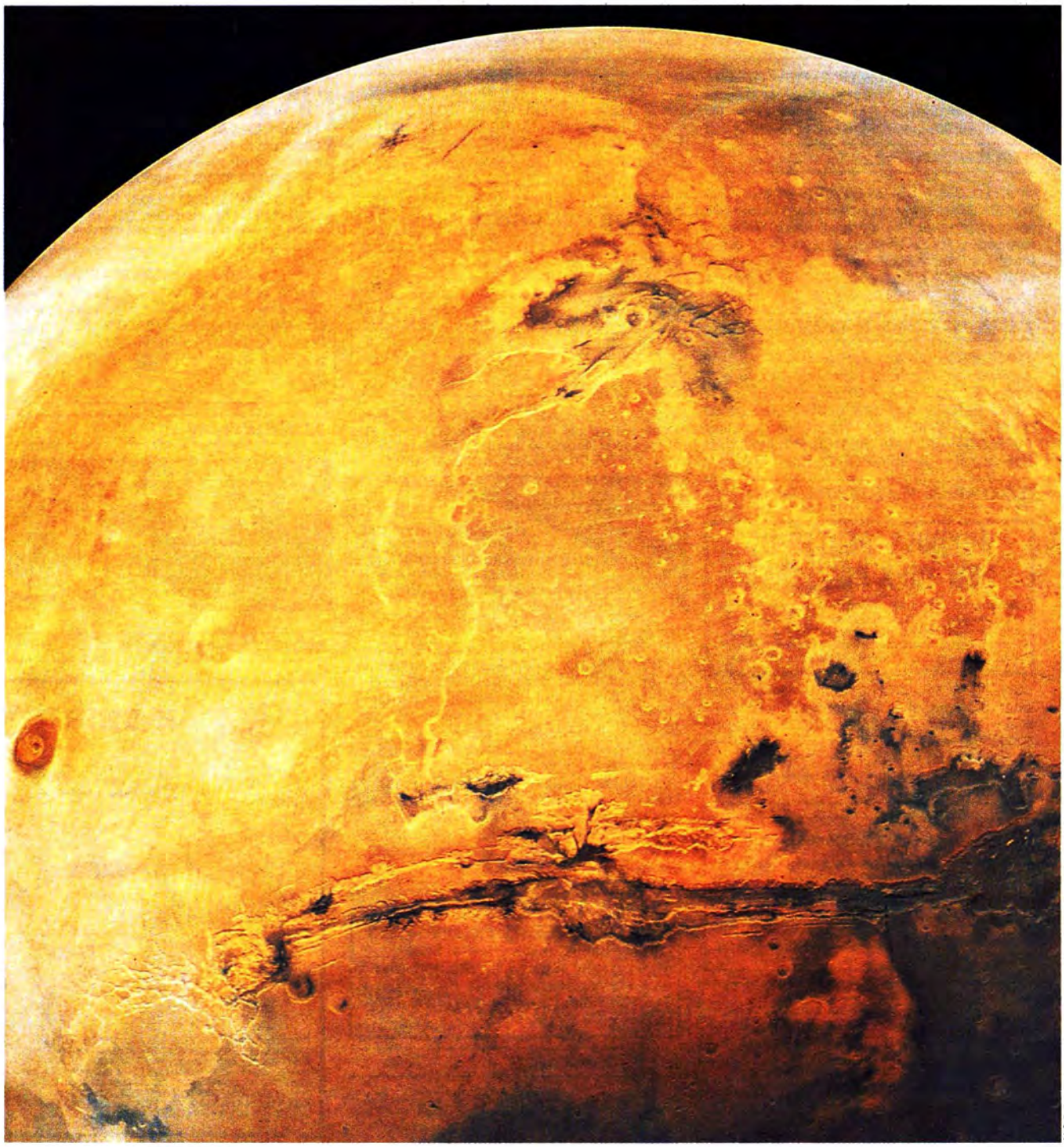
About 1995 a momentous but slow-dawning fact will register on everyone, namely, that we happen to live in the era when Man found a way to reach the stars. At that time we will get on with it: the exploration of the rest of the universe. The long- abandoned idea of a manned mission to Mars will be revived.

Tom Wolfe, 1985



U.S.G.S.

MISSION FILE

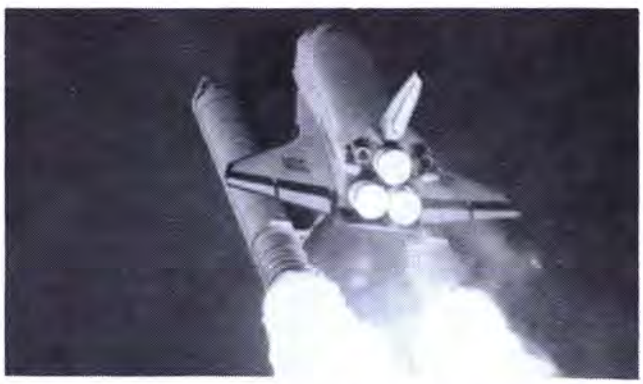
STS-27

LAUNCH:
9:30 A.M. EST, December 2, 1988, Pad 39B, Kennedy Space Center, Florida
LANDING:
3:36 P.M. PST, December 6, 1988, Edwards Air Force Base, California
ORBITER:
Atlantis
ALTITUDE:
Classified. Estimated 210-250 nautical miles
CREW:
Robert "Hoot" Gibson, Commander
Guy Gardner, Pilot
Mike Mullane, Jerry Ross, Bill Shepherd, Mission Specialists
PRIMARY PAYLOAD:
Classified. Believed to be a "Lacrosse" spy satellite with high-resolution radar imaging system.

Shuttle mission 27 was a shot in the dark, so to speak. Officially, Atlantis went up and Atlantis came down. NASA and the Department of Defense wrapped most of the flight's activities in a blanket of military secrecy.

Although the shuttle's payload was classified, most experts agreed that a mammoth spy satellite, code-named "Lacrosse," was stashed in Atlantis' cargo bay. And while NASA was mum on the mission's exact scheduled liftoff time (ostensibly to complicate Soviet tracking efforts), the space agency did release the planned launch date, and announced a three-hour "window" during which the liftoff would occur.

Unacceptable wind conditions scrubbed a launch attempt on December 1. The following morning, Atlantis again sat ready and waiting, but high-altitude winds continued to be a problem until moments before the nominal launch window expired. When the weather improved, NASA mission managers gave shuttle commander "Hoot" Gibson and his crew a hurried "GO" for launch.



Atlantis roared off into a Florida chamber-of-commerce blue sky at 9:30 A.M. Almost immediately, the shuttle stack rolled over and zoomed up the East Coast, bound for a northerly orbit that would overfly much of the Soviet Union. The unusual trajectory—most missions head nearly due east away from the Cape—blasted spectators with a wall of pop-and-crackle noise from the shuttle's rocket engines. It also gave some watchers the illusion that the spacecraft was almost overhead; one radio newsman exclaimed, "We can see right up the tailpipes!"

The shuttle's flight path wasn't the only curious aspect of the ascent to orbit. The checkpoints normally called up to the astronauts by Mission Control ("Go at throttle up." "First stage performance: nominal") were heard plainly, but NASA blacked out the crew's responses in deference to the military nature of their mission.

The space agency had almost nothing to say about the remainder of the flight, but ground observations suggested that the astronauts released the "Lacrosse" reconnaissance satellite sometime during their first six orbits of the Earth. By most reports, the spy-in-the-sky was a real bear: large enough to fill Atlantis' payload bay, equipped with a battery of advanced radar and optical sensors and carrying an extra load of volatile hydrazine maneuvering fuel. Two lightweight solar panels attached to 50-foot deployable arms on either side of the spacecraft gave it a distinctive cruciform layout (and possibly, its name).

If theories about the deployment sequence are correct, astronaut Mike Mullane hoisted Lacrosse gingerly from Atlantis' cargo bay with the shuttle's robot arm. The crew then flew in formation with the huge satellite until they were certain it was functioning properly.

Apparently, Lacrosse's giant solar arrays gave mission controllers some tense moments. The aerospace trade magazine *Aviation Week & Space Technology* reported that the first try at deploying the panels failed; a second command from the ground was needed to get the satellite up and running. According to pre-launch rumor, astronauts Jerry Ross and Bill Shepherd were to attempt a mission-saving spacewalk if something went awry and no other options remained.

Atlantis returned to Earth on the afternoon of December 6. Illuminated by the setting sun, the orbiter swooped in from the north—again, an unusual direction for a shuttle landing—to make a perfect touchdown on the dry lakebed runway at Edwards Air Force Base in California. Photos confirmed that Atlantis' fragile thermal tiles had taken a beating, presumably from falling ice or debris during the eight-and-a-half minute ride to orbit five days earlier. It was rumored that the crew used TV cameras on the shuttle's robot arm during the flight to ensure that the underside tiles were still intact.

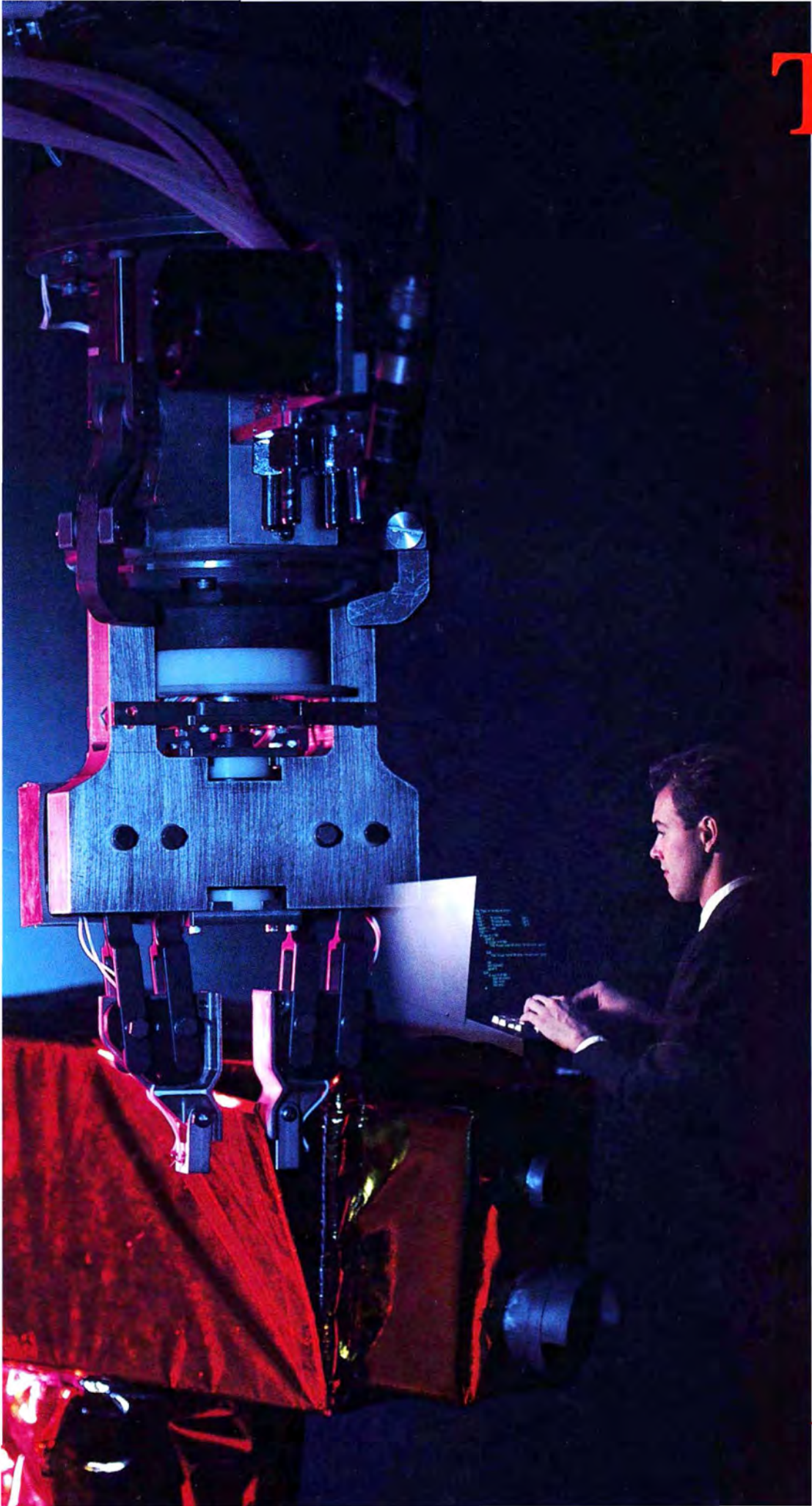
Atlantis' next trip will be anything but a mystery. In April, the orbiter will start the Magellan spacecraft—the first U.S. planetary mission in more than a decade—on its 16-month voyage to Venus.

MISSION FILE

SHUTTLE LAUNCH DATES AND CREW ASSIGNMENTS

MISSION	ORBITER	DATE	COMMANDER	PILOT	MISSION SPECIALISTS	PAYLOAD SPECIALISTS
30	Atlantis	4/28/89	David Walker	Ronald Grabe	Norman Thagard Mary Cleave Mark Lee	—
28*	Columbia	7/1/89	Brewster Shaw	Dick Richards	David Leestma James Adamson Mark Brown	—
33	Discovery	8/10/89	Frederick Gregory	David Griggs	Story Musgrave Kathryn Thornton Manley Carter	—
34	Atlantis	10/12/89	Donald Williams	Michael McCulley	Shannon Lucid Ellen Baker Franklin Chang-Diaz	—
32*	Columbia	11/13/89	Dan Brandenstein	James Wetherbee	Bonnie Dunbar Marsha Ivins David Low	—
31	Discovery	12/11/89	Loren Shriver	Charles Bolden	Bruce McCandless Steve Hawley Kathryn Sullivan	—
36*	Atlantis	2/1/90	Not yet named	Not yet named	Not yet named	—
35	Columbia	3/1/90	Jon McBride	Guy Gardner	John Lounge Robert Parker Jeffrey Hoffman	Ronald Parise Samuel Durrance

*NASA retains the original mission number even when flights are launched out of sequence. All dates are subject to change.



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